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F-22 versus UCAV fixing today's deficiencies leaves questions about tomorrow's dominance

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THESIS

F-22 VERSUS UCAV: FIXING TODAY'S DEFICIENCIES LEAVES QUESTIONS ABOUT TOMORROW'S DOMINANCE

by

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December 2009

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F-22 VERSUS UCAV: FIXING TODAY'S DEFICIENCIES LEAVES QUESTIONS ABOUT TOMORROW'S DOMINANCE

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Submitted in partial fulfillment of the
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LIST OF ACRONYMS AND ABBREVIATIONS

ACC	Air Combat Command
AFA	Air Force Association
ANG	Air National Guard
AOR	Area of Responsibility
CIA	Central Intelligence Agency
CSAF	Chief of Staff of the Air Force
DHS	Department of Homeland Security
DoD	Department of Defense
EU	European Union
FAS	Federation of American Scientists
FY	Fiscal Year
GDP	Gross Domestic Product
IC	Intelligence Community
ISR	Intelligence, Surveillance, and Reconnaissance
JDAM	Joint Direct Attack Munition
MCR	Mission Capable Rate
MTBM	Mean Time Between Maintenance
NATO	North Atlantic Treaty Organization
O&S	Operations and Support
OIF	Operation IRAQI FREEDOM
PRC	People's Republic of China
PPP	Purchasing Power Parity
SEAD	Suppression of Enemy Air Defense
SIGINT	Signal Intelligence
SIPRI	Stockholm International Peace Research Institute
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Aerial Vehicle
USAF	United States Air Force

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I. INTRODUCTION

A. MAJOR RESEARCH QUESTIONS

This thesis evaluates the U.S. government's decision to end F-22 production and shift procurement focus toward first-generation Unmanned Combat Aerial Vehicles (UCAV). This recent decision raises many questions but most importantly, is the shift justified and what affect will it have on the United States Air Force's (USAF) ability to defend the homeland? By switching priorities to procuring medium sized first-generation UCAVs like the MQ-1 Predator and MQ-9 Reaper, what has this done to the USAF's potential to effectively provide homeland defense across the full threat spectrum? The evaluation of this decision involves three subareas that provide a necessary foundation to answer the main research questions. First, an analysis of global defense spending trends comparing the major players in military spending addresses claims that the U.S. has no peer threat warranting continued production of the F-22. Second, a comparison between manned and unmanned flight highlights the advantages to both and why the desire to transition away from manned fighters is considered the way of the future. Lastly, a mission effectiveness assessment between the F-22 and UCAV helps evaluate what affect this decision has on homeland defense and security missions today.

B. IMPORTANCE

Since the end of the Cold War and the collapse of the Soviet Union, the U.S. military has had no peer competitor in conventional war, and after the attacks on September 11, 2001, the focus of the U.S. military has shifted toward fighting violent extremists. The current enemy might have changed but the Department of Defense (DoD) is still charged with defending the United States against a full range of potential threats.

> The core responsibility of the Department of Defense is to defend the United States from attack upon its territory at home and to secure its interests abroad. The U.S. Armed Forces protect the physical integrity of the country through an active layered defense. They also deter attacks upon it, directly and indirectly, through deployments at sea, in the air, on

> land, and in space. However, as the spreading web of globalization presents new opportunities and challenges, the importance of planning to protect the homeland against previously unexpected threats increases.[1]

The F-22 was specifically designed as an air superiority fighter for the USAF. The goal of the program was to use stealth, speed, and advanced technology to produce an overwhelming force to establish air dominance for many years to come. This dominance came at a high price but is deemed necessary due to the importance of air superiority in homeland defense both within U.S. borders and abroad to protect U.S. national interests. The desire for this unique overwhelming capability has faded in recent years in favor of lower cost multi-role weapons systems tailored to current combat situations and countering asymmetric threats. In contrast, UCAVs have gained significant popularity with recent successes in Iraq and Afghanistan in their role as Intelligence, Surveillance, and Reconnaissance (ISR) platforms with weapons employment capability. This popularity and multi-role performance has renewed interest in UCAVs. In addition, organizations such as the Central Intelligence Agency (CIA) and the Department of Homeland Security (DHS) have expressed interest in using these UCAV platforms for other homeland security missions.

Defense funding in air power has shifted from conventional warfare platforms, like the F-22, to systems tailored to countering today's asymmetric threats such as UCAVs. While this change appeals to some senior government officials concerned about fixing asymmetric deficiencies with lower cost multi-role assets, others boast there are additional factors to consider such as the thousands of jobs lost by shutting down production lines. Combining versatility with lower costs makes for an attractive aviation platform but rarely can you both save money and increase effectiveness. The potential to reduce force effectiveness exists when focusing on cost and versatility instead of effective results across the full potential threat spectrum.

[1] Department of Defense, *National Defense Strategy*, 2008, 6.

C. LITERATURE REVIEW

The debate whether to continue to fund costly F-22 production has been highly publicized, as well as politically charged with defense contractors proclaiming the loss of tens of thousands of jobs. At the same time, there has been an increased desire for information providing platforms, such as unmanned aerial vehicles, stemming from the war on terror. Combining these two agendas with the current economic crisis makes every dollar spent an important decision in trade-offs.

Steven Abott writes, "[Secretary] Gates' point in canceling the program is that spending on legacy systems like the F-22 is making it hard to fund the technologies to confront the requirements we currently face."[2] In congressional testimony, both the Secretary of the Air Force, The Honorable Michael B. Donley, and the Chief of Staff of the Air Force (CSAF), General Norton A. Schwartz agreed, stating; "The Air Force examined emerging, advanced threats, and then analyzed our Combat Air Forces' capabilities against them. Our intent was to ensure the proper mix of platforms that meet requirements, while minimizing excess inventory and deriving the most capability from our limited resources."[3] This signals a significant change from previous strategies that desire an overwhelming force, ensuring victory over making war a contest between equally matched powers.

Within the last three years, the Air Force has revisited its decision to purchase 381 F-22 aircraft required for a low-risk force, to 243 for a moderate-risk force that would create an unfunded $13B bill during a dramatically more constrained defense spending era.[4] The decision was re-addressed in May 2009 by the CSAF, concluding that "buying more F-22s means doing less of something else."[5] All of these words suggest that system cost and applicability are driving the decision to cut funding for the F-22, it is just too expensive and there just isn't the need for further F-22 airframes in conflicts we expect to

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[2] Steven Abott, "The F-22 Raptor: Disconnect between Strategic Planning and Program Acquisition," The Henry L. Stimson Center, 2009.

[3] House Armed Services, *Fiscal Year 2010 Air Force Posture Statement*, 4.

[4] Honorable Michael Donley and Gen Norton Schwartz, "Moving beyond the F-22," *Washington Post*, sec. Op-Ed, 13 April 2009.

[5] Ibid.

face in the future.[6] Secretary Gates summed up the future of the F-22 by stating that the "F-22 had no role in the war on terror."[7] While this statement applies to the current conflicts the U.S. is fighting against terrorism, it is reasonable to assume that future conflicts may require access to contested airspace the F-22 was designed to penetrate.

Competing for DoD funding are UCAVs. There are many recognized benefits to UCAVs and rising from their Iraq and Afghanistan war successes, there is an increased demand for these systems. The Fiscal Year (FY) 2010 budget includes a major increase in unmanned aircraft to include 24 additional MQ-9s Reapers, a significant upgrade from the MQ-1 Predator, to support an increase from 34 continuous orbits to 50 by the year 2011.[8] In addition, 4,100 personnel positions were created in the USAF military personnel budget to meet the manning demand this increase in orbits would create, and would increase the overall end strength of the USAF.[9] DHS has also expressed interest in obtaining UAVs adding to their usefulness. The popularity of these systems has piqued interest for border security, emergency relief missions, and interest from federal and state authorities.[10] This broad mission applicability strengthens the UAV stance for increased budgetary consideration.

Advocates for the procurement of additional F-22 aircraft suggest that shutting down production would reduce U.S. international security options, specifically, conventional deterrence in a time when forceful ventures such as the Russian movement into Georgia are still occurring.[11] Even opponents agree that a key element to winning future wars is maintaining conventional force superiority to deter rising powers from

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[6] Anthony H. Cordesman and Hans Ulrich Kaeser, *America's Self-Destroying Airpower: Becoming Your Own Peer Threat* (Washington, D.C.: Center for Strategic and International Studies, 2009), 11.

[7] Ibid., 15.

[8] Donley and Schwartz, *Fiscal Year 2010 Air Force Posture Statement*, 4–5. An orbit in this context defines a specific location in the battle airspace that is assigned to a UCAV for the purpose of preplanned data collection or dynamic re-tasking in response to ground forces support requirements.

[9] Lt Gen Richard Y. Newton, III, Air Force Military Personnel Budget Overview, Presentation to the Subcommittee on Personnel, Committee on Armed Services, United States Senate, 2009, 2–3.

[10] Adam N. Stulberg, "Managing the Unmanned Revolution in the U.S. Air Force," *Orbis* 51, no. 2 (2007), 258.

[11] Rebecca Grant Ph D., *Global Deterrence: The Role of the F-22* (Arlington, VA: Lexington Institute, 2009), 12.

instigating conflict though they feel we can do this with less manned fighters.[12] Additional arguments suggest this smaller force of F-22s will burn through the 8,000 hour design life at increased rate and put the USAF on a faster timeline for developing a replacement for the F-22 or it will require similar costly service life extension plans like today's fighter force.[13] In addition, the current fighter force continues to retire aircraft at an increasing rate, peaking at 180 in 2021, even when considering service life extension plans.[14] This reduction in fighters combined with the expected deliveries of F-35 aircraft would introduce an overall reduction in the fighter force starting in 2015 creating a gap between aircraft desired and aircraft available.[15] This "fighter gap" shown in Figure 1, is not a myth; it is acknowledged by senior leaders within the USAF and DoD but is being addressed in a different way.

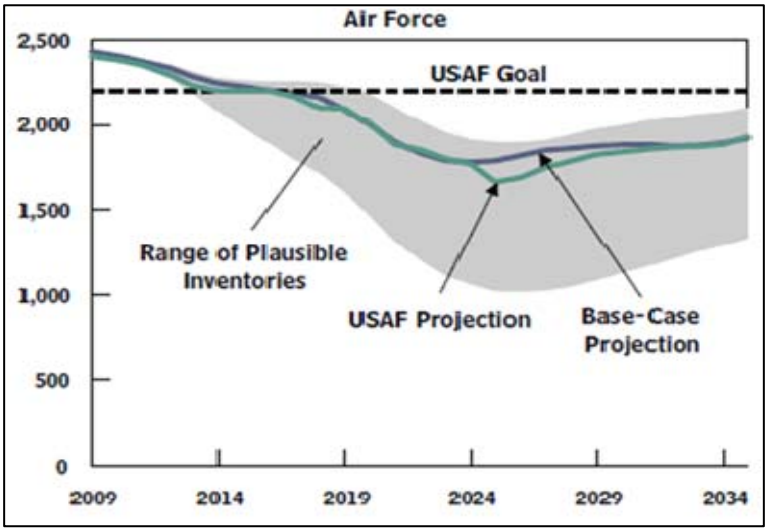

Figure 1. Potential Future Fighter Inventories.[16]

[12] Scott Bates and Zachary Warrender, *Agility across the Spectrum: A Future Force Blueprint* (Washington, D.C.: Center for National Policy, 2008), xi.

[13] Grant, *Global Deterrence: The Role of the F-22*, 11.

[14] Douglas W. Elmendorf, *Alternatives for Modernizing U.S. Fighter Forces* (Washington, D.C.: The Congress of the United states, Congressional Budget Office, 2009), 7.

[15] Ibid.

[16] Ibid., 10.

They are proposing an increase of $4.1B in FY10 to purchase 10 F-35 Joint Strike Fighters as a way to lower unit costs, currently estimated at between $67M and $90M for the AF variant, and speeding up the replacement of current fighter aircraft.[17] The FY2010 DoD budget also supports an expeditious retiring of 250 current fighters to free up an additional $3.5B in the next six years intended to also speed up production.[18] The impact of these measures is currently unknown but the potential exists for a shortfall topping out at 400 fighter aircraft in 2025 provided the F-35 procurement remains at current levels.[19]

Proponents for the advancement of UCAV procurement argue the need for advanced air superiority fighters is the product of a cold war mindset.[20] In today's asymmetric environment the Air Force should fund projects applicable to near-term threats and conflicts that we are likely to face in the future.[21] In addition supporters maintain the combined ISR and armed combat capability from a platform that costs a fraction of manned aircraft is the best use of limited resources. The significant reduction in personal risk to Airmen through remote datalink control Other advantages to UAVs adding to the cost benefits include reduced replacement costs with the ground control suite not at risk thousands of miles away from the battlefield and expected reductions in mishap rates due to increased automation.[22]

There are many arguments for and against automation when discussing air vehicles used to secure the U.S. and its interests. First, the reduction in potential loss of life with the use of UAVs is politically significant by reducing the human costs to war. Second, the growing costs to maintain a high-tech manned force while under pressure to reduce defense spending makes low cost UCAVs appealing. Finally, personnel-related

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[17] Douglas W. Elmendorf, *Alternatives for Modernizing U.S. Fighter Forces*, 46.

[18] Donley and Schwartz, *Fiscal Year 2010 Air Force Posture Statement*, 4.

[19] Douglas W. Elmendorf, *Alternatives for Modernizing U.S. Fighter Forces*, 7.

[20] Bates and Warrender, *Agility across the Spectrum: A Future Force Blueprint*, 38–39.

[21] Ibid., 41.

[22] Rich Butler, "The U.S. Shift Beyond Capital Assets" In *Transforming Defense Capabilities: New Approaches for International Security*, ed. Scott Jasper (Boulder, CO: Lynne Rienner Publishers, Inc., 2009), 160.

costs such as retirement benefits, basic cost of living subsistence, and health care costs are growing at unsustainable rates within the current military budget plans.[23] It is reported that retired military members are deserving of over $650B in benefits that the Pentagon currently cannot afford.[24] By replacing pilots with unmanned systems the savings potential is worth a serious look provided there is an actual reduction in manpower requirements and not just a shift in spending.

From the other perspective, if the goal is save money by cutting your human costs, current UCAVs might not be the answer. With systems such as the MQ-9 there are requirements for three operators at any one time increasing the human related costs instead of reducing them.[25] This fuels the desire for greater automation allowing a single UCAV crew to operate multiple aircraft simultaneously. This added tasking combined with a current requirement for "man-in-the-loop" might reduce the capability for effective human intervention should the need arise.[26] In addition, operating unmanned systems currently requires telecommunication datalinks, which are vulnerable to jamming, or even possibly hacking, allowing control of your systems by the enemy.[27] While such occurrences have not been reported, the amount of intrusions in military computer networks suggests it is only a matter of time before these new systems are penetrated. Finally, the use of unmanned systems to fight wars from a safe distance could become problematic when up against an adaptive and intelligent enemy.[28] Not only does removing human costs to battle have the potential to make war a more appealing option in settling political disputes but unintended consequences such as perceived cowardice might actually work against a force employing such tactics. While

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[23] Armin Krishnan, "Automating War: The Need for Regulation," *Contemporary Security Policy* 30, no. 1 (2009), 175.

[24] Ibid.

[25] Ibid.

[26] Ibid.

[27] Ibid., 176.

[28] Douglas Peifer, "Riskless War: Technology, Coercive Diplomacy, and the Lure of Limited War," http://smallwarsjournal.com/blog/journal/docs-temp/243-peifer.pdf, (accessed 10 May 2009), 9.

the end state of secure datalink operations, significant automation, and accepted UCAV warfare would realize the advantages of unmanned systems the current platforms do not quite meet those objectives.

Each side to this debate has a strong case as to why funding should be concentrated their way. The enormous costs associated with the F-22 program have fueled the search for more efficient uses of USAF money. Since inception, cost overruns have increased the average procurement cost of an F-22 from $110M in FY99 to an estimated average of $154M in FY08 but what is often left unaddressed is the significant increase in unit cost associated with the decision to reduce the number of F-22s produced from 750 down to 187.[29] In addition, during a telephone conversation with the author on May 21, 2009, Air Force officials shared the results of a recent study conducted by Headquarters Air Force. It concluded that the operation and support (O&S) costs per flight hour for the F-22 are approximately $38K compared to $26K and $17K for the F-15 and F-16, respectively. Though other USAF sources claim the difference is much less when comparing variable costs per flight hour; those numbers are $19K for the F-22 and $17K for the F-15 in FY07 dollars.[30] In comparison, the MQ-9 Reaper unit cost is approximately $53.5M in FY06 dollars but includes four aircraft and a ground control station (GCS).[31] Because of the infancy of the UCAV programs, there are no current studies on O&S available, but Air Force officials concluded that based on fuel consumption alone, the cost per flight hour for the MQ-9 would be considerably lower even if all other support requirements cost the same. Combining the low fuel cost and relative simplistic maintenance requirements for UCAVs of today make it an attractive platform for future procurement.

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[29] Cordesman and Kaeser, *America's Self-Destroying Airpower: Becoming Your Own Peer Threat*, 4.

[30] Ronald O'Rourke, *Air Force F-22 Fighter Program: Background and Issues for Congress*, (Washington, D.C.: Congressional Research Service, 2009), 26.

[31] USAF UAS Factsheet, http://www.af.mil/information/factsheets/index.asp, (accessed 21 September 2009).

D. METHOD AND OVERVIEW

In the next chapter, an analysis of the defense spending trends of the primary military powers helps define the security environment the USAF must prepare for in the near future. These trends are used to evaluate the decision to stop production of F-22 aircraft at 187, and shift procurement priority to UCAVs as an effective means to provide future air power. In defining the east and west defense spending sides, the U.S. and European Union (EU), as a collective, will define the west while Russia and the Peoples Republic of China (PRC) will represent the east. Chapter III consists of an analysis of the advantages of both manned and unmanned systems to shed light on the draw toward unmanned flight in future aircraft procurement. This analysis will include a brief summary of the F-22 and first-generation UCAVs, as well as cost implications to both systems. Chapter IV provides an effectiveness comparison between the F-22 and UCAVs using four fundamentals of aircraft effectiveness. It evaluates the impact to the USAF and its ability to accomplish the missions relevant to Homeland Defense in the previously suggested security environment. Reliability, survivability, availability, and versatility are the four measures of effectiveness used to compare these platforms. These measures of effectiveness are not mission specific due to the difference in primary roles for the F-22 and the current UCAV systems. This eliminates the potential for prioritizing one mission in homeland defense over another. The final chapter contains conclusions and recommendations based on the research conducted. The initial conclusion of this thesis suggests the decision to shut down production of the F-22 and ramp up procurement of UCAVs addresses today's deficiencies in irregular warfare, but as an unintended consequence, reduces the current and future ability of the USAF to protect the U.S. and its interests abroad, across the full spectrum of potential threats.

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II. DEFENSE SPENDING ENVIRONMENT

Since the turn of the century, defense spending has been on the rise globally. In 2008, the world totals for defense spending equaled approximately $1.464T corresponding to 2.4% of the world gross domestic product (GDP).[32] The global war on terrorism initiated by the U.S. and most evident in the wars in Iraq and Afghanistan, have raised questions about future U.S. military expenditures. With this change in focus, what will be the impact on defense spending worldwide? Does the enormity of the west defense budgets show signs of decreasing? Is the east mounting an opposing giant in defense fueled by their recent economic successes? What impact does the lack of transparency in east defense spending have on these trends? These are the major questions that will be addressed in this section, and will aid in understanding future security environments.

In order to understand where the future of defense spending is headed, first an analysis of trends over the last decade is presented, using total spending data and spending as a percentage of GDP. This section will classify the West as represented by the U.S. and the European Union (EU) as a collective. Representing the East will be Russia and the People's Republic of China (PRC). Combined these countries make up the vast majority of defense spending in the world and thus will adequately represent the future trends in global military expenditures as well as peer competitor capabilities. After presenting each player's defense spending trends, a comparison between them will be presented and the possible implications they represent to each other in the current security environment. In addition, the paper will discuss these trends and the implications they have on the future of defense spending to both sides. The initial research suggests that even though the world economy has taken a downward turn, defense expenditures can be expected to continue to rise and possibly increase the military burden on societies.

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[32] Sam Perlo-Freeman and others, "Military Expenditure" In *SIPRI Yearbook 2009: Armaments, Disarmament and International Security* (Solna, Sweden: Stockholm International Peace Research Institute, 2009), 179.

A. DATA AND ANALYSIS

The data presented within this research is compiled mainly from the Stockholm International Peace Research Institute (SIPRI) a well known research center in the area of international security. By confining the majority of the data compilation to this one source, any estimated military budgets will remain constant for comparison purposes. In order to analyze the defense spending from different perspectives and drawn additional conclusions, trend data is presented as total spending by a country in constant specified year dollars, as well as a percentage of GDP. While the total amount spent by a country gives an assessment in real terms as to what assets can be purchased or personnel supported, using percent GDP highlights the burden the military budget places on that country's economy. An analysis of the data over the last decade will provide trends that will also be discussed, allowing for predications on where defense expenditures will most likely go in the next few years, and what these trends could mean for the security environment.

B. SUMMARY OF EAST AND WEST DEFENSE SPENDING

1. U.S. Defense Spending

It is no surprise that the world's largest economy has the largest military spending. The U.S. makes up approximately 41.5% of global military spending.[33] The next closest competitors are the combined countries of the EU accounting for an estimated 20% of global military expenditures. Table 1 shows the rise in U.S. military expenditures since 2000 in total U.S. dollars spent. Much of the increase in spending can be contributed to the conflicts the U.S. entered into post September 11, 2001. The most significant increase in spending is in operations and maintenance, as well as procurement. This is common due to the unrelenting pace of war, and the extreme working conditions military equipment must navigate.

[33] Sam Perlo-Freeman and others, *SIPRI Yearbook 2009: Armaments, Disarmament, and International Security*, 182.

	2000	2001	2003	2005	2007	2008[a]	2009[a]
Outlays at current prices[b]							
DOD, military	281.1	290.2	387.2	474.1	529.8	583.1	651.2
Military personnel	76.0	74.0	106.7	127.5	128.8	137.4	129.1
O&M	105.8	112.0	151.4	188.1	216.6	225.1	241.5
Procurement	51.7	55.0	67.9	82.3	99.7	130.5	142.8
RDT&E	37.6	40.5	53.1	65.7	73.1	74.7	78.6
Military construction	5.1	5.0	5.9	5.3	7.9	10.2	15.1
Family housing	3.4	3.5	3.8	3.7	3.5	4.3	3.4
Other[c]	1.5	0.3	−1.6	1.5	0.2	0.8	40.8
DOE, military	12.1	12.9	16.0	18.0	17.1	17.8	18.2
Other, military	1.2	1.6	1.6	3.2	5.7	6.4	5.7
Total national defence	**294.4**	**304.8**	**404.8**	**495.3**	**552.6**	**607.3**	**675.1**

Table 1. U.S. Outlays for the Department of Defense.[34]

Many theories have been presented to justify this enormous defense budget. First, individuals with higher incomes tend to accept higher levels of military spending than do those with lower incomes.[35] Applying this theory to the U.S., which comprises over 23% of the world GDP, one could argue that this higher output level and standard of living would call for larger defense spending.[36] Second, the U.S. is commonly thought of the as the "police of the commons," areas such as international waters, to provide some level of global security. This added responsibility primarily falls on the shoulders of U.S. military forces and could justify greater overall military spending than other countries. This could have a doubling effect when looking at percentage comparison; simply put, an increase of one percent spending for the U.S. could allow a decrease in one percent spending of another country but a two percent difference between the two when compared. Compound this for each country involved and one could argue this adds to the imbalance leaning toward the U.S.

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[34] Sam Perlo-Freeman and others, 186. The Outlays represents expenditures and are expressed in US$B. The 2008 and 2009 data are estimates.

[35] Leonard Dudley and Claude Montmarquette, *The Demand for Military Expenditures: An International Comparison* (the Netherlands: Martinus Nijhoff Publishers, 1981), 9.

[36] International Monetary Fund, "World Economic Outlook Database." Data mined by the author from the International monetary Web site for the United States and compared to the world GDP from the same source.

Others offer the argument that the U.S. has maintained such high military spending rates to maintain its position as the sole super power in the world.[37] While other nations in Europe and Asia reduced their spending levels after the Cold War era ended, the U.S. maintained high spending rates. Some argue this was in part because the "military industrial complex" continued to provide justification for the current levels of spending.[38] Another argument suggests that the high rate of spending by the U.S. does not protect the whole of the world but only those countries the U.S. favors.[39] In either case, whether one is for or against the high level of U.S. defense spending, it is obvious that the U.S. significantly outspends the nearest competitor in total dollars spent.

As previously mentioned the U.S. economy is also a world leader so looking at military expenditures as a percentage of GDP allows for analysis of the burden the military places on the economy. Figure 2 shows the military expenditure as a percentage of GDP over the last decade. Before 2001, defense spending maintained at approximately 3% of GDP. An upward trend since 2001 shows the added conflicts the U.S. has entered have added an addition percentage point in burden to the economy. What is difficult to quantify is what affect is appropriate. Critics of this increase suggest that times of conflict allow for haphazard spending patterns and loose budgets while proponents cite increased equipment wear and unpredicted expenses as reason for the added spending and thus increased burden on the overall economy.

[37] Anup Shah, *World Military Spending*, http://www.globalissues.org/article/75/world-military-spending, (accessed 16 September 2009), 16.

[38] Ibid.

[39] Ibid.

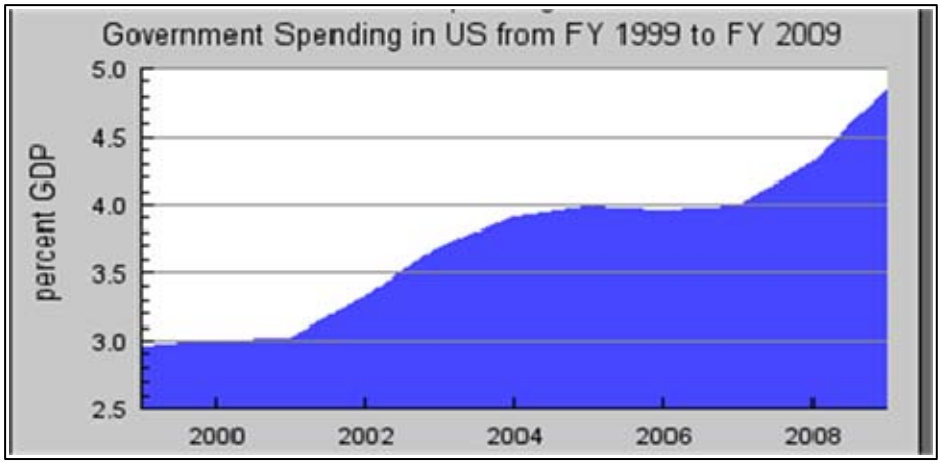

Figure 2. U.S. Defense Spending as a Percent of GDP.[40]

One area that is not addressed in the data analysis is how the Department of Homeland Security (DHS) budget factors into this spending equation. Since its creation shortly after the events of 9/11, DHS budget has grown to over $52.5B in 2009 an increase of approximately 10% from 2008.[41] As complicated a sorting problem as defense budgets, the DHS budget is even more so with 21 agencies all sharing a piece of this budget. It is difficult to identify what money could be considered for Homeland Defense versus what money is used for domestic police actions. For the sake of simplicity, these numbers are not considered part of the defense spending in the U.S.

2. EU Defense Spending

Using figures from 2001 to 2006, the EU defense spending has increased only just slightly. Total spending went from $234B in 2001 to $242B in 2006 and can mostly be attributed to the six signatories of the Letter of Intent on defense (LoI-6).[42] These countries; France, Germany, Italy, Spain, Sweden, and the UK comprise approximately

[40] Christopher Chantrill, "U.S. Government Spending," http://www.usgovernmentspending.com/defensechart30.html. Data is actual defense spending as reported by the Office of Management and Budget for the U.S. Census Bureau.

[41] Department of Homeland Security, *Budget-in-Brief 2010* (Washington, D.C.: Department of Homeland Security, 2009), 15.

[42] Wan-Jung Chao, Gregory Sanders, and Guy Ben-Ari, *Trends in European Defense Spending, 2001-2006* (Washington, D.C.: Center for Strategic & International Studies, 2008), 1–2.

80% of total EU defense spending.[43] Though the EU has shown an increase in defense spending overall it is a mere 3% between 2001 and 2006 suggesting more of stabilization in spending rather than growth. The influx of 10 new members to the EU and five of those members also joining the North Atlantic Treaty Organization (NATO) encompassed much of the absolute increase in spending over this five year span.[44] As Figure 3 demonstrates, the primary defense spenders maintained fairly stable spending levels, and only a few new members had significant percent increases in spending. The graph also supports the addition of new members such as Latvia, Lithuania, and Estonia significantly attributed to the positive growth rate as a percentage over this five year span but because of their small real dollars spent did not significantly change the overall trend of minimal defense spending growth.[45]

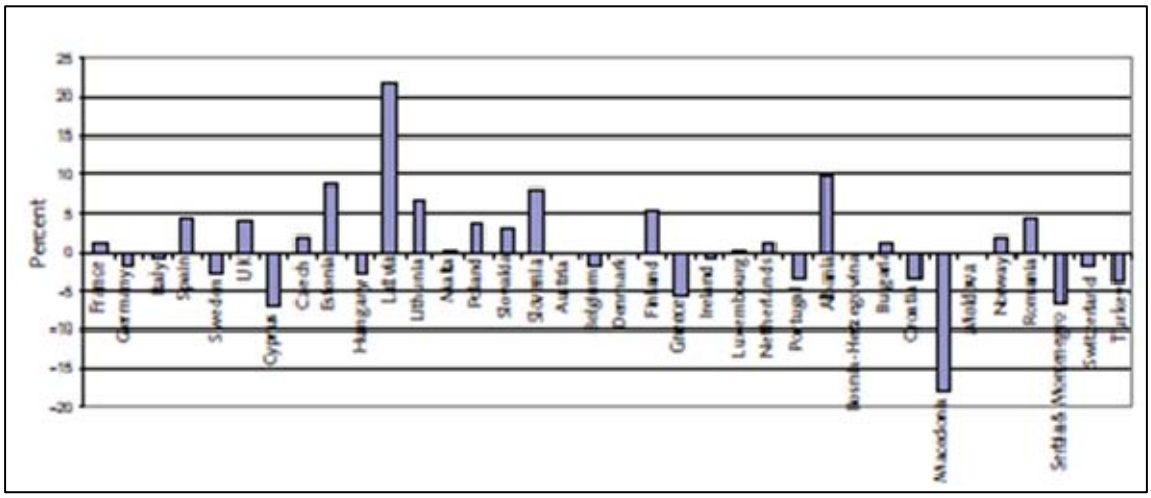

Figure 3. CAGR of EU Defense Spending (2006 Dollars).[46]

In addition to looking at EU total defense spending, it is important to assess if this was merely a sign of economic growth, or if it increased the military burden to the economy as expressed in terms of GDP. Figure 4 supports the claim that the vast

43 Wan-Jung Chao, Gregory Sanders, and Guy Ben-Ari, *Trends in European Defense Spending, 200–2006*, 2.

44 Ibid., 10.

45 Ibid.

46 Ibid., 9. CAGR is the compounded annual growth rate between 2001 and 2006.

majority, including the major LoI-6 defense spenders, have decreased their military burden as a percentage of GDP. This could represent a significant change in mindset for European defense policy. Some suggest that Europe has moved past believing there is a large conventional threat that looms over their continued security and their current military equipment and readiness is sufficient to maintain their sovereignty.[47] On the other side of the debate are those that suggest the European military forces are outdated and must modernize to maintain interoperability with the U.S. to effectively contribute to NATO security objectives.[48] New NATO members such as Bulgaria and Romania have cited interoperability with current NATO forces as justification for higher than recommend level of military burden but continue to decrease this burden as represented in Figure 4.[49] Over the last few years, the trend continues with the EU maintaining a slightly decreasing level of military burden on its economy, supporting the claim that EU military spending trends suggest they do not perceive a serious military threat.[50]

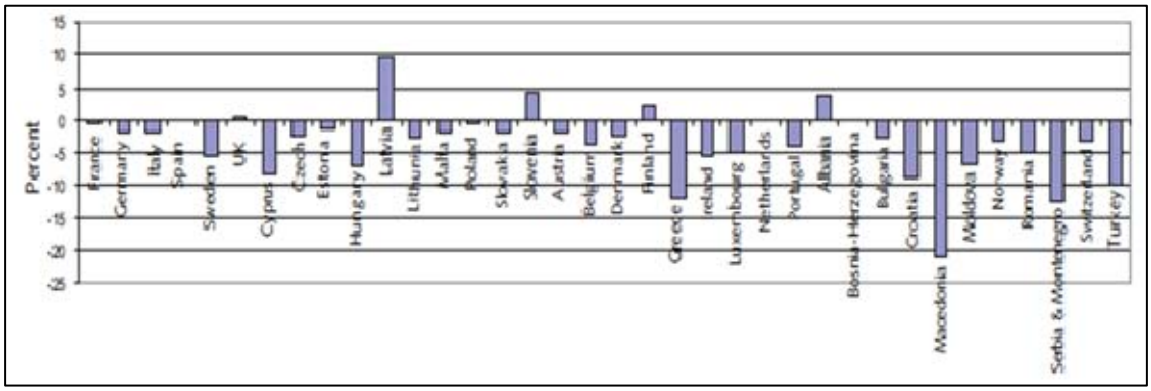

Figure 4. CAGR of EU Defense Spending as a Percentage of GDP, 2001–2006.[51]

47 Jose' Ignacio Torreblanca, "EU Defense: The Numbers Don't Add Up," http://www.ecfr.eu/content/entry/commentary_torreblanca_on_european_defence, (accessed on 20 September 2009).

48 Rob de Wijk 1954-, "European Military Reform for a Global Partnership," *The Washington Quarterly* 27, no. 1 (2003), 197.

49 Chao, Sanders and Ben-Ari, *Trends in European Defense Spending, 2001–2006,* 10.

50 Perlo-Freeman and others, *Military Expenditure,* 191.

51 Chao, Sanders and Ben-Ari, *Trends in European Defense Spending, 2001–2006,* 11.

3. Russian Defense Spending

Moving on to the countries representing the east, Russia and China both represent some difficulties in analyzing data for the purposes of trends. Most of the figures are estimates due to the lack of transparency of their government practices. The numbers might be viewed as expressing what it is these countries want others to think versus the actual defense spending levels.[52] But taking these figures as fact, we can see that Russian total spending levels have been on the rise significantly over the past decade. This significant increase, shown in Figure 5, comprises one of the largest percentage increases in the world, second only to China.[53] Some attribute this to the combined explosion in economic growth Russia has experience from natural resource sales with the desire to regain its regional and world power status.[54]

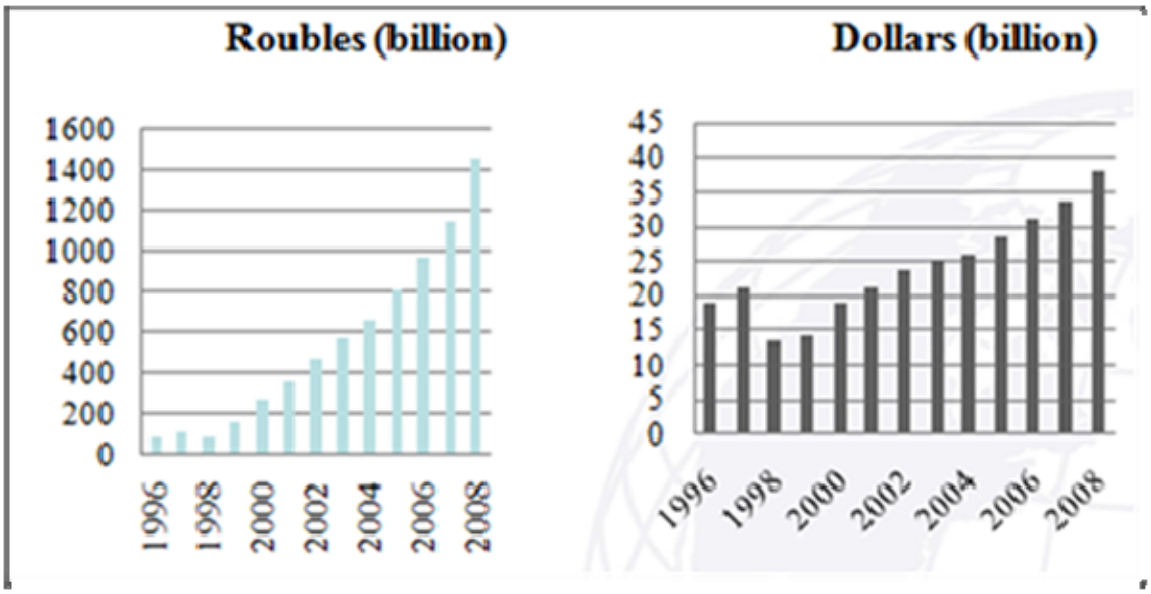

Figure 5. Comparison of Russian Total Defense Spending in Roubles and U.S. Dollars (in constant 2005 currency).[55]

[52] Office of the Secretary of Defense, *Military Power of the People's Republic of China* (Washington, D.C.: Office of the Secretary of Defense, 2009), 32.

[53] Perlo-Freeman and others, *Military Expenditure*, 181.

[54] Ibid.

[55] Ibid. Compiled by author from raw data associated with SIPRI 2009 Yearbook.

To support the claim that most of this rise in raw spending can be contributed to the economy prosperity in Russia, the military burden on the economy has remained relatively constant at 4% GDP as seen in Figure 6. Even though reports claim Russia is reaching a new level of global power, the proof is less persuading. Internal conflict between its political and military agencies has led to conflicting procurement plans and inconsistent strategic direction culminating in a weakening of its real military strength.[56] Despite these claims, Russia did show it is willing to engage in armed conflict to show its regional dominance during a five-day skirmish in Georgia in late 2008.[57]

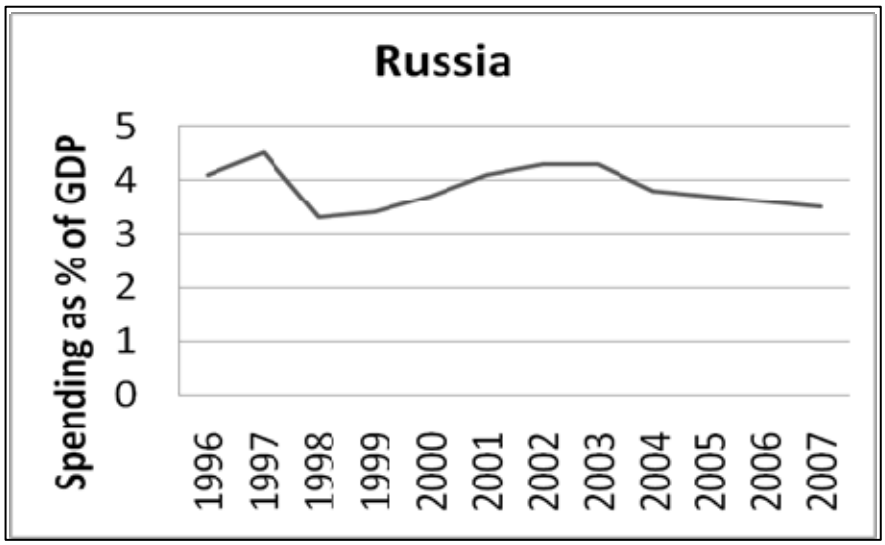

Figure 6. Russian Military Burden on the Economy.[58]

It is worth noting again though, that these are just estimates of Russian defense budgets because the empirical data is not accessible. In order to come to more accurate estimates, a specific concept was used during the Cold War by the Central Intelligence Agency (CIA) called purchasing power parity (PPP). Basically, spending levels are

[56] Michael Wills and Mercy Kuo, "Defence Policymaking in Strategic Asia: International and Comparative Perspectives," In *Handbook of Defence Politics*, eds. Isaiah Wilson III and James J. F. Forest, 1st ed. (London, U.K.: Routledge, 2008), 173.

[57] Maria Levitov and Lyubov Pronina, "Russia Boosts Defense Budget to Record $50 Billion," http://www.bloomberg.com/apps/news?pid=20601095&sid=aiyuNBcJa_ko&refer=east_europe, (accessed 10 September 2009).

[58] Perlo-Freeman and others, *Military Expenditure*. Compiled by author from raw data associated with SIPRI 2009 Yearbook.

estimated based on perceived capabilities and what they would cost in U.S. dollars. It is not known whether or not the current Russian estimates have used PPP or simply based on reports from Moscow. Though it is not difficult to see this practice has the potential to over inflate the actual levels of spending by the shear nature of estimation. One thing is for certain, the Russian government is reporting higher levels of spending and the modernization of Russian air forces is not a secret. While producing advanced fourth-generation fighters like the Su-30, Russian Air Forces are in line to purchase over 70 Su-35s, a more versatile multi-role version of the Su-30.[59] Right now Russian economic growth and subsequent ability to modernize its military seems to be tied to their natural resources so as long as business is good, the military burden will remain manageable.

4. Chinese Defense Spending

As part of the National Defense Authorization Act for Fiscal Year 2000, Public Law 106–65, the Secretary of Defense is required to provide a report to Congress discussing the military Power of the People's Republic of China (PRC).[60] The data presented is taken from this report as well as GDP data estimated by SIPRI. China has taken steps to improve their transparency when it comes to military expenditures, but so far has been limited to their use of a Simplified Reporting Form for submission to the United Nations.[61] This form breaks out defense spending into Personnel, Training & Maintenance, and Equipment sectors but does not require any further delineation in spending.[62] PRC leaders chose this form over the Standardized Reporting Form suggesting they are not yet willing to commit fully to the idea of military transparency which hampers any confidence-building they may have been trying to accomplish.[63]

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[59] Rebecca Grant Ph D., *Losing Air Dominance* (Arlington, VA: Mitchell Institute Press, 2008), 17.

[60] Office of the Secretary of Defense, *Military Power of the People's Republic of China*, 1–66.

[61] Ibid., 33.

[62] Ibid.

[63] Ibid., 32.

As is well known, the PRC economy has shown tremendous growth over the past decade, averaging between 8% and 12% annual growth rates shown in Figure 7. Equally important is the percentage growth in military spending over this same period. While there were a couple of years that the military growth rate was below that of the overall economy, on average China has been significantly ramping up their defense spending. It should also be noted that these are figures reported by Chinese government reports, not estimates made by the U.S. or other entities.

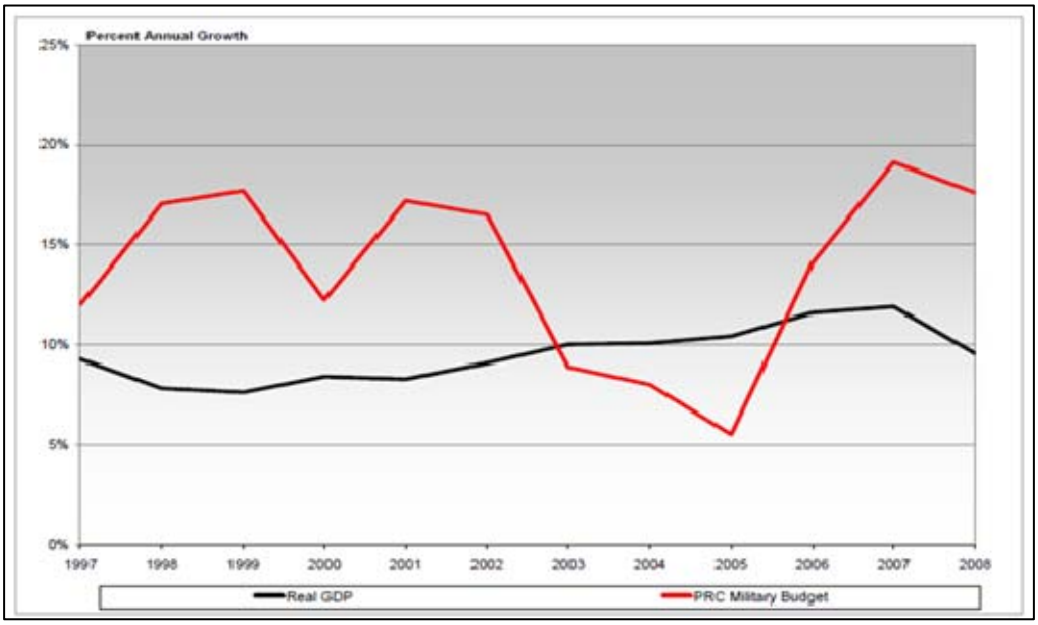

Figure 7. Annual Real GDP and Growth Rate of China's Military Budget[64]

Within the report to congress, DoD applied "PPP" which included projected expenses for strategic forces, foreign acquisitions, military R&D, and paramilitary forces to capture what the U.S. felt to be a more accurate representation of China's military spending. Those results presented as low and high estimates along with China's official military budget are shown in Figure 8. The difference is staggering; averaging the high and low estimates still puts Chinese spending estimates at twice what is being reported. This data suggests either the U.S. has overestimated the cost of these publicly known programs, which is a pitfall to this practice, or the Chinese are underestimating their

64 Office of the Secretary of Defense, *Military Power of the People's Republic of China*, 34.

spending to project to the international community a smaller than actual military machine. SIPRI estimates the military burden on China's economy at approximately 2% GDP and China has maintained that constant level for the last seven years.[65]

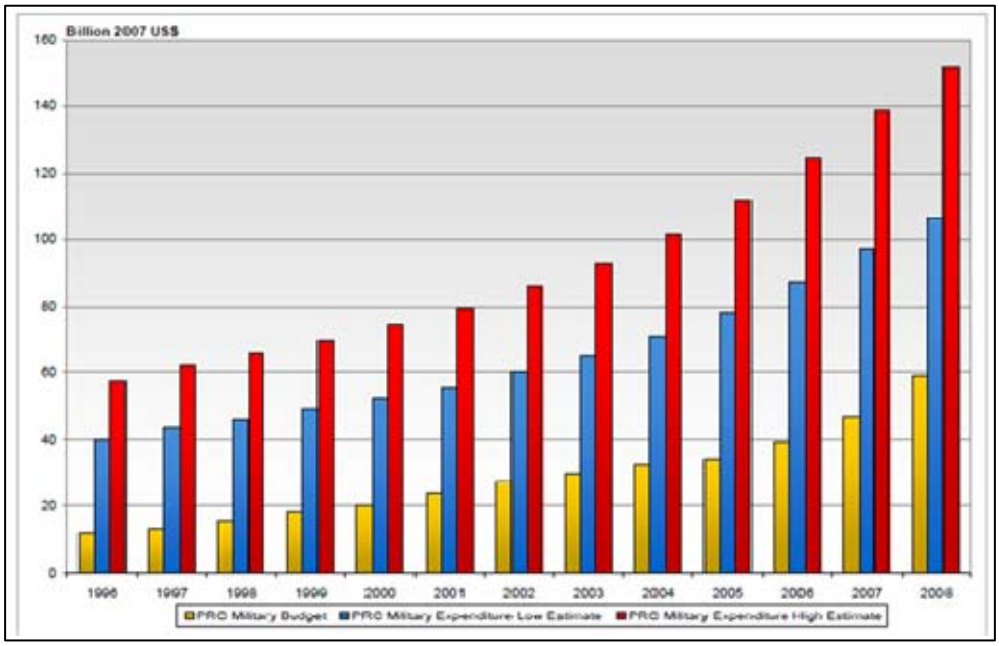

Figure 8. PRC Military Budget and Estimated Military Expenditures[66]

What is true, and very apparent, is China's military modernization program. As an example, the PRC has been buying destroyers and submarines from Russia, as well as producing indigenous nuclear-powered submarines with ballistic missile capabilities.[67] This rapid growth in naval power, which has the potential to become larger than the U.S. fleet by 2020, is explained away by Beijing as "in line with China's growing economic strength and emergency as a great power."[68] Part of this explanation is no different than explanations used to justify the U.S.'s enormous military expenditures; they are simply

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[65] Perlo-Freeman and others, *Military Expenditure*. Data mined by author from SIPRI 2009 Yearbook.

[66] Office of the Secretary of Defense, *Military Power of the People's Republic of China*, 32.

[67] ForeignPolicy.com, "The List: The World's Biggest Military Buildups," http://www.foreignpolicy.com/story/cms.php?story_id=4051, (accessed 10 September 2009).

[68] Wills and Kuo, *Defence Policymaking in Strategic Asia: International and Comparative Perspectives*, 171.

protecting their new found economic wealth. China is the second largest economy as measured by GDP in the world, and if it continues at its current growth rate has the potential to surpass the U.S.[69]

C. COUNTRY COMPARISONS

Bringing all the data together you can see from Figure 9 that the U.S. dominates military spending throughout the world with Europe second, but China and Russia have a significant piece of the pie and their spending trends suggest that portion will continue to grow. Even without the current additional spending required by the Iraq and Afghanistan conflicts, the U.S. is still the principal determinate of world military spending trends. Europe as a collective union spends a considerable amount but that share will most likely dwindle should the EU continue to put defense spending lower on the priority list than China and Russia. This is of great concern to the U.S. as the other player in the west. The trend toward decreasing military economic focus suggests that the use of force mentality is obsolete in the eyes of the EU.[70] With the U.S. projecting hard military power as a viable and still used tool in foreign policy, this peaceful political culture has the potential to put the relationship between the U.S. and the EU to the test in an era demanding bilateral action.[71]

When comparing the military spending of these countries as a function of GDP it puts some of the debate back into perspective. Each side has a country that spends at a rate between roughly 3–4% and another that is down around 2% over the last 10 years as seen in Figure 10. Looking at the U.S. and Russian trends of the last ten years as compared to the EU and China, it seems as though the U.S. and Russia budget more toward capabilities, and accept to some degree a variance in military burden to the economy shown buy the fluctuation is percent GDP.

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69 International Monetary Fund, *World Economic Outlook Database 2009.*

70 Wijk, *European Military Reform for a Global Partnership*, 200.

71 Ibid., 200–203.

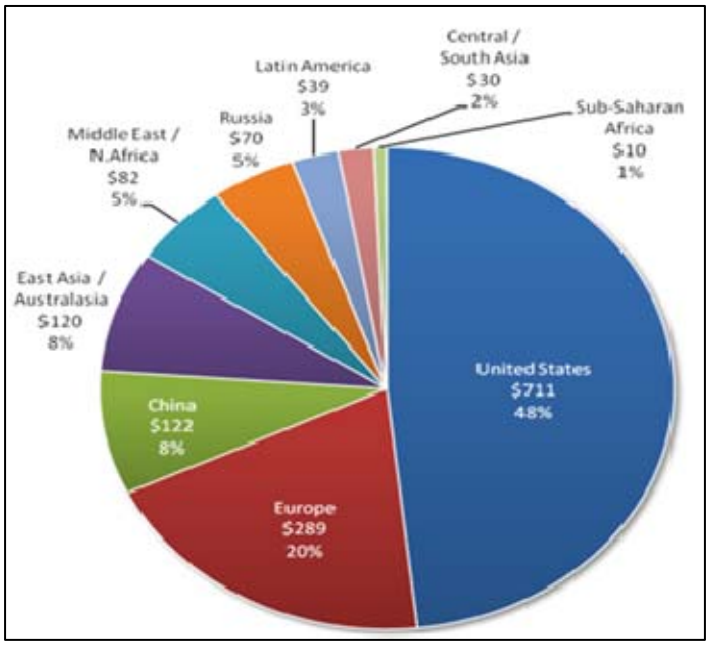

Figure 9. 2008 Military Expenditures (US$B).[72]

Whereas the EU along with China seems to focus on making sure their military spending burden maintains relatively constant at 2% of GDP. For the EU, this is in line with the already mentioned NATO recommendations but for China one might assume they look at the overall level of 2.4% for global military expenditures as a percent of GDP and use this as a guide. The obvious difference comes in economic performance when following this philosophy. In China, economic prosperity has provided significant increases in military spending without adding burden to the economy but this is not the case in the EU. A more modest economy growth portfolio means the level of actual spending also remains modest.

Perhaps a better comparison between these countries, that can shed some light on what can be expected from them in the next few years, is to look at the increases in the last few years in spending, and also as a percentage increase. Large increases in military expenditures can mean any number of events most of which have already been addressed. But what is difficult to understand is what affect these trends have on policy of potential

[72]Anup Shah, *World Military Spending*, 11.

adversaries. Looking at Figure 11 from an east perspective, it looks as though the U.S. is spending enormous amounts of money on defense, when compared in absolute dollars. This has the potential to increase the east military spending patterns to keep pace with the west or even to try and catch up for their own survival in the security environment.

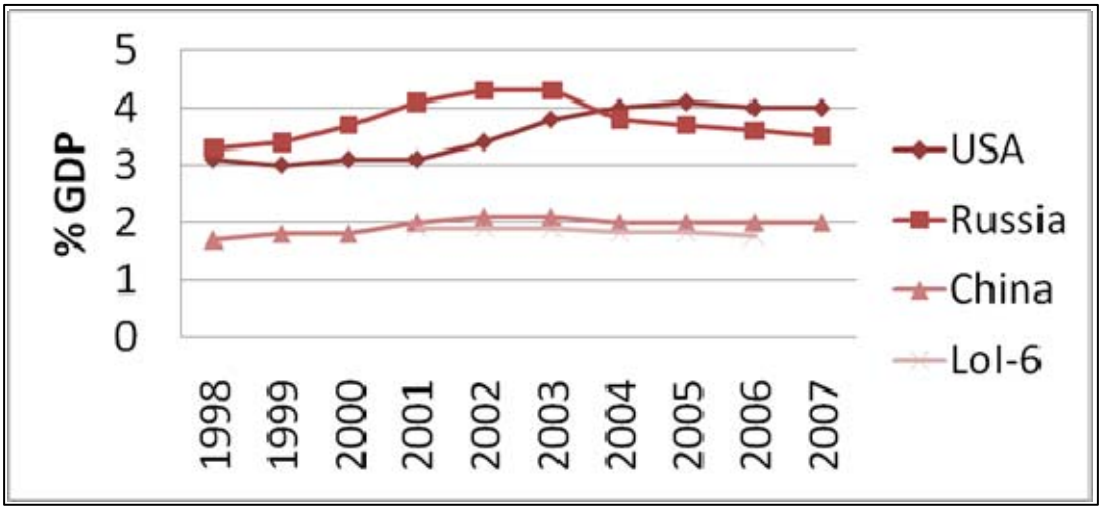

Figure 10. Defense Spending as a Percent of GDP, 1998–2008 (2005 U.S. dollars).[73]

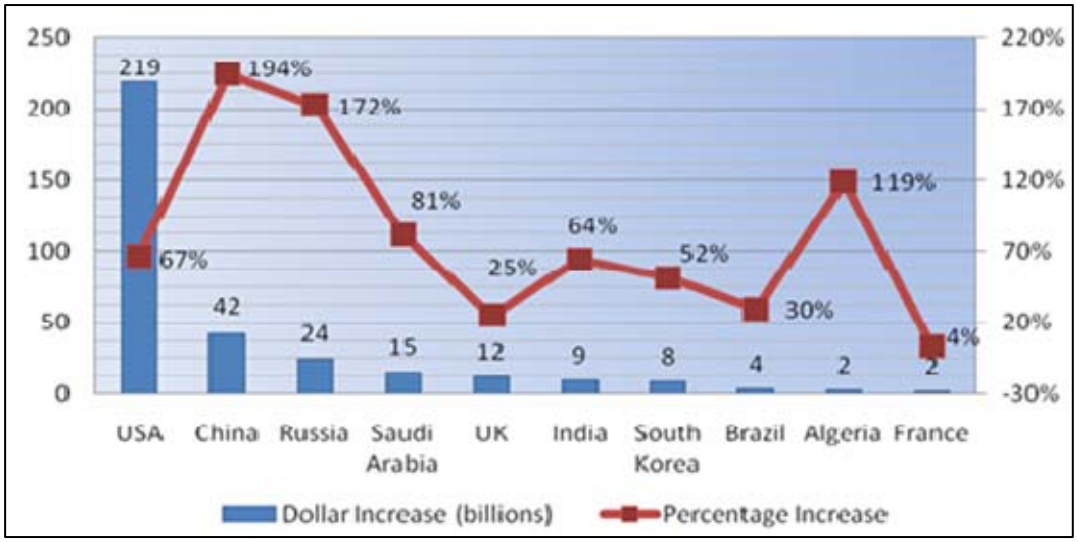

Figure 11. East and West Military Expenditure increases, 1999–2008.[74]

[73] Perlo-Freeman and others, *Military Expenditure*. Data was compiled by the author from data mining the SIPRI 2009 Yearbook.

[74] Anup Shah, *World Military Spending*, 4.

If the west were to look at these trends in spending, they would notice the enormous percent increase in defense spending for both players in the east. This could mean that both Russia and China feel they are currently in an inferior position when it comes to military strength and must take drastic steps in order to maintain their national security. The modernization trends for both countries suggest this is the case, but the data, as related to GDP, do not show this increase in burden that one might expect even with the economic growth in both countries. One explanation presented by DoD suggests the actual spending levels of these countries are more than they report.[75] But it should also be noted that for budgets of their size, any significant modernization in efforts to catch up to the U.S. or even the EU would take large percentage increases in comparison.

D. IMPLICATIONS FOR THE FUTURE

It seems that the enormity of the current U.S. defense budget has had, and will continue to have, a significant effect on defense spending for both China and Russia, as well as what seems to be a dependency of such trends on the part of the EU. Before looking forward, it might help to understand where this enormous U.S. defense budget originated. A large portion of the increase can be attributed to the Cold War. Studies have shown that public opinion during that period concerning the appropriate magnitude of U.S. defense spending played an important role in policy making.[76] In addition, changes in U.S. defense spending were also directly related to changes in Soviet spending and significantly influenced by the estimated spending gap.[77] This spending gap estimation that may or may not have existed resulted in over $100B in increases to the U.S. military expenditures in the 1980s.[78]

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[75] Wills and Kuo, *Defence Policymaking in Strategic Asia: International and Comparative Perspectives*, 173.

[76] Charles W. Ostrom Jr. and Robin F. Marra, "U.S. Defense Spending and the Soviet Estimate," *The American Political Science Review* 80, no. 3 (1986), 838.

[77] Ibid.

[78] Ibid., 839.

The difficulty comes in reversing this trend and unfortunately it looks as though this might continue into the next era. While U.S. defense spending may have stalled somewhat in the 1990s, it has been on the upswing since 2000.[79] The potential now exists for the U.S. to apply this same estimation logic to China and continue this increased spending alongside the demands imposed by the wars in Iraq and Afghanistan. The Secretary of Defense, Robert Gates, has also made it known that the U.S. must be prepared to engage in all aspects of combat ranging from conventional to irregular warfare and all variations in between.[80] It would seem difficult to do so without restructuring the military forces which will cost money. While the Defense Secretary has put major weapons systems on the chopping blocks, such as the F-22, navy destroyers, and the Army Future Combat System, the money has just been moved as opposed to saved.[81]

So, it seems that the military budget of the U.S. will most likely continue to rise, setting the stage for yet another battle for security. One glimmer of hope, oddly enough, was the recent economic meltdown that has affected most of the world. Focusing funds toward economic growth to keep from spiraling into a deeper recession, instead of toward military capital, seems legitimate but often times the exact opposite takes place. Individuals that are accustomed to higher incomes now feel more vulnerable and have the tendency to accept larger expenditures to keep them from further impoverishment.[82] For the U.S., the economy has been running at a relatively high level of efficiency, thus, growth rates have tended to be slower, and any significant defense spending increase shows both greater burden, percent of GDP goes up, and absolute cost. The EU is using

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79 Anup Shah, *World Military Spending*, 2.

80 "Gates Speech on FY-10 Budget Recommendations," http://www.insidedefense.com/secure/display.asp?docnum=dplus2009_0998&f=defense_2002.ask, (accessed 20 August 2009).

81 Ibid.

82 Dudley and Montmarquette, *The Demand for Military Expenditures: An International Comparison*, 19–20.

its collective as a way to combat significant increases in defense expenditures, as well as a different mindset toward peaceful resolutions and will continue to use the 2% GDP as a benchmark.[83]

The Russian economy has grown consistently since 2001 though is predicted to take a hit just like most other economies in 2009. Their success has been directly linked to natural resources suggesting limitation on further growth but in the near term the Russian economy in performing well. More money facilitates additional defense spending to protect its wealth, but Russia is also using the expansion of NATO on its western front as a legitimate security concern supporting modernization. What does this means to the west? Russia will continue to grow militarily and export more equipment through foreign military sales potentially increasing global security risks to the west. China has the convenience of economic growth to explain away large and speedy increases in defense expenditures. Also, the tremendous secrecy prevents a true analysis of their trends in spending. Continued indigenous reverse engineering of Russian systems adds to China's self sufficiency and ability to keep costs down while increasing military strength. China will continue to use vulnerabilities to their economic machine as reasons to continue to expand their military and cite, "we are no different than the U.S." as a comeback to critics. The U.S. could request, if this is true, that they then must accept the increased global security responsibility such as "patrolling the open seas." This presents a Pandora's Box situation if not kept in check that could potentially threaten the U.S. homeland. On the other hand, China may view any direct threat to the U.S. as an indirect threat to its continued economic growth based on significant ties the two economies share.[84] This theory puts China as an ally in future security environments and thus would pose less of a threat to western powers.

E. CONCLUSION

Does the enormity of the West defense spending show signs of decreasing? The short answer is it depends. Shifts in spending trends within the U.S. DoD, moving away

[83] Wijk, *European Military Reform for a Global Partnership*, 200–204.

[84] Thomas P. Barnett, *The Pentagon's New Map (*New York, NY: G.P. Putnam's Sons, 2004), 122.

from major weapon systems for future capabilities towards irregular and asymmetric warfare, hinted at the possibility that military spending will decrease but really the U.S. is looking at efficiency instead of budget cuts. Conflict supplements continue though more will most likely be spent in Afghanistan now that the U.S. is slowly withdrawing from Iraq. At some point though, the U.S. will eliminate supplemental spending but a significant problem that will continue to keep U.S. military spending at high levels is the reconstitution of western military assets. The last decade has put enormous strains on western military capital that must now be replaced to maintain at least a status quo in capability. As is commonly known, military inflation rates associated with modernization can be upwards of 10% causing significant burden to the economy.[85] Unless economic growth increases significantly the military burden on western economies has the potential to increase unless lower levels of capability are accepted.

What impact does the secrecy of East defense spending have on these trends? As seen in the Cold War, using PPP is a dangerous tool leading to overestimating your opponent. At least in the U.S., defense budgets are moving back toward a threat based mindset away from capabilities based which has the makings of increased spending to both match Russian and Chinese modernization expenditures and continue to fund military efforts in the war on terror. And finally, is the east mounting an opposing giant in defense fueled by their recent economic success? The trends suggest that while these economies continue to present better than average growth rates so too will their military expenditures. Applying the same concept of those that have more to lose are willing to spend more to protect it, the east will continue to spend more in efforts to protect what they have built. While the capabilities of peer competitors in the east are no match for current U.S. and NATO forces, defense acquisition decisions made today will affect the ability to maintain that dominance in years to come. In particular, the U.S. must carefully weigh decisions to end weapons programs designed to maintain its overwhelming force for the next 20 years.

[85] Chao, Sanders and Ben-Ari, *Trends in European Defense Spending, 2001–2006,* 16.

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III. ANALYSIS OF MANNED AND UNMANNED FLIGHT

This section presents a comparison between the advantages of manned and unmanned flight. This debate is not new and will most likely continue for many years but its significance has increased of late and warrants discussion in this research. The analysis begins with the advantages of manned flight which includes firsthand knowledge of the battlefield, aircraft performance, and self-preservation. The next section focuses on the F-22 with a brief history of the weapon system followed by performance data in recent operational exercises and concludes with cost implications to this platform. Then the discussion shifts to UCAVs showing how the thirst for information has increased the role of UCAVs in war, as well as homeland security. In addition, the complex cost implications to UCAVs will lend to final conclusions in the comparison between manned and unmanned flight.

A. ADVANTAGES OF MANNED FLIGHT

One of the arguments for manned flight is linked to the advantages of having firsthand knowledge of the battlefield to better control the situation and improve decision-making capabilities. The situational awareness of a pilot on the battlefield increases the capacity for effective task engagement and prioritization over that of an operator who is well removed from the battlefield.[86] Presence in the battlespace allows a pilot to analyze the environment, assess the appropriate course of action, then implement with the flexibility to fine tune their decisions during employment. In addition to the decision-making advantages of manned aircraft, performance of the aircraft adds to their success.

Most manned aircraft, such as the F-22, are designed with superior speed, detection software suites, and maneuverability contributing to operational flexibility and quick response times.[87] These characteristics also increase the survivability of the

[86] Robert M. Taylor, *Human Automation Integration for Supervisory Control of UAVs* (Farnborough, United Kingdom: Her Majesty's Stationery Office, 2006), 7.

[87] Kumar, *Tactical Reconnaissance: UAVS Versus Manned Aircraft*, 6.

weapon system for the same reasons UCAVs take the pilot off the battlefield, to reduce the probability of casualties. Great care is taken in designing manned aircraft so they are durable as well as safe for pilots and is in contrast to the expendable mindset used for UAV production.

This last area of debate relates to the moral and ethical issues to warfare. By using manned aircraft in combat missions that require lethal force, the combatants are seen as justified in their actions, as opposed to using UCAVs to do the killing. This perceived humanity in risking human life while fighting wars is seen as bravery, as opposed to using UAVs to do the same, which can be characterized as cowardice and cold. The current use of UCAVs by the U.S. is a sign to insurgents that America "is afraid to sacrifice troops in combat."[88] By placing a pilot in this difficult position, there is an appreciation for the "moral value of killing and the value of human life."[89] There is an added importance in making the right decision when self-preservation becomes part of the equation.

1. The Epitome of Manned Aircraft

The primary objective of the F-22 program was to develop an aircraft that would absolutely dominate the skies through counterair operations.[90] As stated by General Richard E. Hawley, "Air superiority is the prerequisite for success in all our military operations: on land, at sea and in the air."[91] This end objective directly contributed to the meticulous design process that emphasized performance, as well as reliability and survivability to achieve the highest mission-capable rate. The F-22 combines stealth technology with superior speed and integrated avionics to produce the world's most

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[88] Mark Mazzetti, "The Downside of Letting Robots Do the Bombing," *The New York Times*, 22 March 2009, http://www.nytimes.com/2009/03/22/weekinreview/15mazzetti.html (accessed 22 July 2009).

[89] Taylor, *Human Automation Integration for Supervisory Control of UAVs*, 4.

[90] Steve Pace, *F-22 Raptor: America's Next Lethal War Machine* (New York, NY: McGraw-Hill, 1999), 85.

[91] Ibid., 92.

advanced tactical fighter in history.[92] To add to its capabilities, the ability to carry air-to-ground munitions was included later in the design phase but only in ways that would not deter from its air superiority role.

The F-22 was the U.S. Air Force's answer to increasing advances by the former Soviet Union in development of advanced tactical fighters like the Su-27 and the associated AA-11 "Archer" and AA-10C "Alamo" missile systems.[93] But more importantly, it would be replacing the F-15, which held the title as the top air superiority fighter since its inception in 1976. The F-15 ,as well as F-16 fighter aircraft, while still in production today and sold overseas, are reaching the end of their design life cycle in the U.S. military and the F-22 is the next generation in tactical fighters. The F-22 will replace the F-15 in all aspects of homeland defense to include Operation Noble Eagle and the associated alert posturing around the continental U.S., Alaska, and Hawaii.

The F-22 also plays an important role in conventional deterrence. The U.S. military is a source of deterrence against other countries embarking on actions seen as unfavorable. Having weapon systems that dominate in key missions is crucial to America's ability to use conventional deterrence as a viable way to protect U.S. interests at home and abroad.[94]

2. Proven Performance

In the passing of the torch from the previous air-to-air combat king, the F-15C, to the F-22 one would expect there would be an aerial battle to prove this occasion. The author has personally been in many such battles and the F-22 had performed above expectation. In the beginning of the F-22 program back in 1991, the Raptor chief test pilot Paul Metz flew against an equally experience pilot in and F-15C. Though the detailed results were classified, Metz said: "I can assure you that the Raptor's talons are far more deadly than two, four or even ten F-15s."[95]

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92 Steve Pace, *F-22 Raptor: America's Next Lethal War Machine* (New York, NY: McGraw-Hill, 1999), 86.

93 Grant, *Global Deterrence: The Role of the F-22*, 9.

94 Ibid.

95 Pace, *F-22 Raptor: America's Next Lethal War Machine*, 75.

Once the F-22 became operational in 2005, it would soon be tested in simulated air to air combat during a two week exercise in Alaska. In May 2006 the author, assigned to the 27th Fighter Squadron from Langley AFB, VA, participated in NORTHERN EDGE, an exercise to test operational war plans and work on joint mission capability between the Navy, Air Force, and Marines. The F-22 combined with F-15C from Elmendorf AFB, AK to provide air superiority during these intense combat simulations. The mission results speak to the dominating effectiveness of the F-22 in the air-to-air arena. Over the two-week exercise the F-22 established an overwhelming 144 to zero kill ratio and 97 percent mission effectiveness rate. The results from the first F-22 participation in the well-known "RED FLAG" exercises at Nellis AFB, NV were just as impressive.[96] The 94th fighter squadron accumulated an impressive 36-to-1 kill ratio, an unofficial record for Red Flag.[97]

3. Overwhelming Capabilities, Overwhelming Costs

With extreme capability comes extreme cost even before considering the cost of delayed production and changes to design specifications. Just as the cost of a Ferrari represents its uniqueness and top performance in automobiles, the F-22 represents these characteristics in aircraft. Looking at the two previous stealth platforms, the B-2 bomber priced at approximately $2.1B and the F-117 fighter/bomber estimated between $45M and $120M, it is apparent that stealth means higher cost.[98] Combine this pricey technology with the utilization rate of current tactical fighters and the costs become a serious factor. After restructuring the F-22 program acquisition schedule multiple times, the end result was a $64B weapon system numbering 187 aircraft.[99] That is approximately $343M per aircraft or $143M if research and development costs are subtracted.

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[96] RED FLAG is a mock combat scenario held over a two week period. It is designed to test combat tactics and skills in realistic and challenging combat situations. While no actual threat aircraft like the Su-27 or MiG-29 are used, F-15, and F-16 aircraft emulate the weapons and maneuver potential of these aircraft.

[97] Lawrence Spinetta, "Raptor Flag," *Combat Aircraft*, February 2007.

[98] FAS, "Aircraft Specifications," http://www.fas.org/programs/ssp/man/uswpns/usaircraft.html (accessed 21 September 2009).

[99] Cordesman and Frederiksen, *Is Defense Transformation Affordable? Cost Escalation in Major Weapons Programs*, 14.

While procurement costs are significant, so too are the operating and support (O&S) costs. A study conducted by the Air Force Studies and Analysis Agency (AFSAA) compared a F-22 fleet of 234 aircraft with the same number of F-15C aircraft to evaluate O&S costs per squadron of 24 aircraft in one year, as well as over the life of the program (FY02-33).[100] The F-22 O&S costs in Base Year 2005 dollars were found to be $134.6M per squadron/year during steady state operations as compared to $126.3M for the F-15C and $32.6B over the life of the program.[101] While reducing the end state total number of aircraft reduces this life time cost, it is still a staggering $25B for 179 operational F-22s.

While the need for a replacement to the F-15 had not changed, the enemy had. After the fall of the former Soviet Union and the end of the Cold War, many did not see the need for this single-role air superiority aircraft. Program survival meant spending even more money to get the coveted "multi-role" label. The U.S. Air Force senior officials did two things: they changed the requirements of the F-22, adding the ability to drop air-to-ground munitions, and renamed the aircraft the F/A-22 reminiscent of the F/A-18 multi-role fighter for the Navy. These changes may have saved the program from abandonment, but the mid-design requirement change compounded the cost overrun problem and may have given current senior leaders valid economic reasons to stop production.

B. THE APPEAL OF UNMANNED AIRCRAFT

Besides the movement toward more technologically advanced systems, there are other reasons why the U.S. military is moving in the unmanned flight direction. The missions favoring UAVs have been identified as the "Dull, Dirty, and Dangerous."[102] The dull refers to extended loiter time missions such as ISR data collection or missions far exceeding the accepted normal crew day of approximately 12 hours for a pilot. The

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[100] BGen C.D. Moore, *Selected Acquisition Report on the F-22* (WPAFB, OH: Department of Defense, 2007), 52–53.

[101] Ibid. The estimations used AFI65-503 Cost and Planning Factors, as well as information provided by the contractor's Affordability Analysis.

[102] *Unmanned Systems Roadmap, 2007-2032* (Washington, D.C.: Office of the Secretary of Defense, 2007), 33.

ability to switch operators while the UCAV is airborne allows for normal crew rest and work cycles.[103] The dirty missions are those that would require the UCAV to be exposed to either chemical, biological, or nuclear environments not suited for human operations. This is also an important interagency capability for use in homeland security disaster roles. The use of UCAVs would increase the success rate of these missions by eliminating the time of exposure issues with humans. The final missions described as dangerous are just that, missions that traditionally have a higher level of associated risk such as deep interdiction and suppression of enemy air defenses (SEAD). By using UCAVs in these missions, it lowers the potential for loss of human life should the aircraft be shot down.[104] There is a common undertone to each one of these missions and that is the preservation of human life and expendability of UCAVs.

Casualties will always be a part of defending the freedoms Americans enjoy but sacrificing airmen when there is a viable alternative seems insensitive to human life. It also makes political sense to support programs that have the potential to save human lives while still accomplishing the mission.[105] Playing to the American casualty adverse culture bodes well for arguments favoring UAVs over manned aircraft.

Taking the human out of the cockpit also changes aircraft design by eliminating the physiological requirements. Unmanned aircraft can be designed to withstand gravity forces that no longer are limited by human endurance which can increase maneuverability.[106] There are also added performance and design benefits to removing the need for a cockpit. The aircraft aerodynamics is improved by reduced drag and the internal storage capacity could be used for added fuel or sensors increasing the range or capabilities of the aircraft. UAVs make no demands on the aircraft designer in areas such

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[103] *Unmanned Systems Roadmap, 2007-2032* (Washington, D.C.: Office of the Secretary of Defense, 2007), 33.

[104] Ibid.

[105] Krishnan, *Automating War: The Need for Regulation*, 175.

[106] Department of the Air Force, *The U.S. Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle Strategic Vision* (Washington, D.C.: Department of the Air Force, 2005), 6.

as ergonomics, life-support, or life-saving systems. This simplification significantly reduces the number of design problems often adding to time delays and increased costs.[107]

1. UCAVs Take Center Stage

The attacks of 9/11 have been called an intelligence failure. The inability of the intelligence community (IC) to put the pieces of the puzzle together with credible sources and warn decision makers called for an increase in knowledge base and information sharing. The 9/11 commission report cited unity of effort in sharing information as an important step in connecting the dots to prevent events such as these terrorist attacks from happening in the future.[108] The commission report made a recommendation that the President should stress to the major national security institutions the importance of the "information revolution" and should take steps toward eliminating the technical issues preventing this change.[109] For the military, which encompasses 85 percent of the IC, this would mean investing in its ISR capabilities and information sharing. UAVs, specifically the RQ-1 Predator, were fresh off of success in the Balkans in the late 1990s and had already been inside the borders of Afghanistan with the CIA adding to their applicability in this specific area of operations.[110] The capabilities of persistent surveillance combined with "eyes on" the battlefield that could be shared by a number of institutions seemed the perfect fit to the information revolution.

UCAVs like the MQ-1 Predator and MQ-9 Reaper have a primary role in providing persistent ISR capabilities to U.S. forces in combat.[111] They are ideally suited to this mission due to advantages of unmanned aircraft mentioned earlier such as long

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[107] L.F.E. Coombs, *Fighting Cockpits 1914-2000: Design and development of military aircraft cockpits* (Airlife Publishing Ltd: England, 1999), 176–177.

[108] National Commission on Terrorist Attacks upon the United States, *The 9/11 Commission Report* (Franklin, TN: Hillsboro Press, 2004), 416–418.

[109] Ibid., 418.

[110] Thomas G. Mahnken, *Technology and the American Way of War* (New York, NY: Columbia University Press, 2008), 201.

[111] The original RQ-1 Predator was designed as purely an ISR platform. The later versions of the Predator added bomb dropping capabilities changing the designator to MQ-1 to denote its multi-role capability.

loiter time and human casualty risk reduction. The ability to share the information collected to multiple receivers simultaneously allows the Combatant Commanders real time situational awareness on the battlefield and provides the tactical commander invaluable information of enemy positions for effective tactical maneuver.[112] Matching strike capability to the ISR platform was inevitable especially after reports of finding Bin Laden with Predators but lacking the ability to take him out immediately.[113]

> The Predator is described as a "killer scout"—dedicated chiefly to ISR but with an ability to shoot at targets of opportunity. However, the Reaper is defined as a "hunter killer," meaning that it is dedicated to strike and yet still has sizeable ISR capabilities, including electro-optical, infrared, low-light TV, and synthetic aperture radar.[114]

Arming UAVs, drastically reduced the time between finding a possible target and engaging once the target is confirmed to be hostile. The process in commonly referred to as Find-Fix-Track-Target-Engage or F2T2E.115 Before the addition of air-to-ground weapons to UAVs, extensive coordination was required to relay target locations from the ISR platform to a fighter or bomber aircraft. The time to destroy the target was also extended due to the transit time of a strike aircraft from its CAP to the designated target area. In the global war on terror and the use of irregular warfare tactics, close air support (CAS) is a vital asset to the ground forces prosecuting attacks. UCAVs have been identified as an effective platform in both the ability to find targets and provide CAS. This multi-role capability seems to have married the two missions most critical to the conflicts the U.S. is currently engaged and those perceived as most likely in the future.

Since the start of the war on terror in 2001, Predator and Reaper systems have been very effective finding and neutralizing insurgents. Current UCAVs have been credited with the elimination of numerous Taliban and Al Qaeda leaders including Salim

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[112] David Kumashiro, "Microsoft, Al-Jazeera, and the Predator," (Maxwell AFB, AL: Air Command and Staff College, 2005), 16–17.

[113] Ibid.

[114] John Tirpak, "Rise of the Reaper," *Air Force Magazine*, February 2008, 37.

[115] F2T2E describes the process from initially finding an object through final clearance to destroy while maintaining positive contact with the object either electronically or visually.

Sinan al-Harethi in November 2002 and Haitham al-Yemeni in May 2005.[116] The most recent UCAV hunt and kill missions in Afghanistan and Pakistan have claimed the lives of nine out of twenty senior Al Qaeda operatives.[117] While these mission successes lend credit to the Predators air-to-ground capabilities, its real effectiveness lies in ISR. Of the almost 11,000 mission flown in 2007 and 2008, only 244 missiles were employed. In contrast, over 16,000 hours of video is transmitted per month for real time analysis and situation reporting from 34 orbits.[118]

2. The Complicated Cost Environment

To date the total procurement expenditures for the MQ-1 and MQ-9 are $3.5B and $1.6B respectively. While the total invested in the more capable MQ-9 is about half that of the MQ-1, the quantity of airframes purchased is significantly less at 81 compared to 468.[119] Though the actual numbers the USAF has received so far is much less, 48 and 291.[120] While the cost comparison between UCAVs and the F-22 is complicated there are some areas that have yet to be addressed that could drive the cost of operating UCAVs much closer to that of manned aircraft such as the F-22.[121] In fact, one could argue the UCAV personnel costs are greater due to the added crewmembers and the desire for 24-hour coverage.[122] The Chief of Staff of the Air Force, General Norton Schwartz recently highlighted the added manpower requirements in a speech to the first graduating class of UAV pilots trained in basic flight skills but with no previous major weapons system experience.

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[116] Mahnken, *Technology and the American Way of War*, 202.

[117] 3D Security, "The Cost of Drone Strikes in Pakistan and Afghanistan", http://www.3dsecurity.org/sites/3dsecurity.org/files/Drone%20Strikes%20Policy%20Brief.pdf (accessed 14 October 2009).

[118] Christopher Drew, "Drones Are Weapons of Choice in Fighting Qaeda", *The New York Times*, 17 March 2009, http://www.nytimes.com/2009/03/17/business/17uav.html (accessed 22 July 2009).

[119] Ted Nicholas, Rita Rossi, *U.S. Military Aircraft Data Book*, 31st ed., section 5 (Fountain Valley, CA: Data Search Associates, 2009), 6.

[120] Ted Nicholas, Rita Rossi, *U.S. Military Aircraft Data Book*, 29th ed., section 9 (Fountain Valley, CA: Data Search Associates, 2009), 2 and 8.

[121] Christopher Bolkcom, *Homeland Security: Unmanned Aerial Vehicles and Border Surveillance* (Washington, D.C.: Congressional Research Service, The Library of Congress, 2008), 5.

[122] Adam Stulberg, *Managing the Unmanned Revolution in the U.S. Air Force*, 260.

> To support each new CAP, we will need 140 more Airmen, half of whom are intelligence professionals… Each new CAP also requires at least seven vehicle operators [pilots] and seven sensor operators – ideally, ten each, to avoid the surge conditions that you've been experiencing for an extended period here.[123]

General Schwartz also commented on the explosion in flight hours in recent years. The first 12 years of the Predator program ending in 2007 produced 250,000 flight hours.[124] That same number of hours took less than two years to accomplish since 2007 and current rates suggest achieving another quarter million hours in just 13 months.[125] While there are no current estimates to the cost implications to the addition of 4,100 personnel allotted for these orbits as presented earlier, or what utility is realized by 250,000 hours of flight time per year.

Yet, another area contributing to UCAV costs that is difficult to evaluate is satellite communications. Air Force officials at Air Combat Command (ACC) headquarters reported the current lease for commercial bandwidth will reach a peak of $43M in FY11 with 50 orbits. With many aspects to the transformational military being tied to satellite communications, it would be difficult to associate all of new satellite costs to UAV programs, but there is an acknowledged link and cost that can be associated.[126] The cumulative effect of these associated costs still suggests that the cost of current UCAV weapons systems is still considerably less than the F-22.

Both the MQ-1 and MQ-9 benefit from availability of off-the-shelf technologies and short design to implementation timelines.[127] Other aspects such as minimal redundancies, a single engine design, low payload capacity and a lack of defense systems all contribute to significant cost savings. As UCAV capabilities increase, so too will their

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[123] Gen. Norton Schwartz, "The Future of Unmanned Systems: UAS 'Beta Test' Graduation," http://www.thefreelibrary.com/The+future+of+unmanned+systems:+UAS+%22Beta+test%22+graduation.-a0210868573 (accessed 2 October 2009).

[124] Ibid, 2.

[125] Ibid, 3.

[126] Anthony H. Cordesman and Paul S. Frederiksen, *Is Defense Transformation Affordable? Cost Escalation in Major Weapons Programs* (Washington, D.C.: Center for Strategic and International Studies, 2006), 39–40.

[127] Rajesh Kumar, *Tactical Reconnaissance: UAVs Versus Manned Aircraft* (Maxwell AFB, AL: Air Command and Staff College, 1997), 24.

unit cost. Improvements in speed, range, maximum altitude and air-to-ground weapons employment all contributed to the doubling of costs between the MQ-1 and the MQ-9.[128] This trend is bound to continue as UCAVs strive to realize the better performance potential suggested by taking out the pilot and physiological constraints of manned aircraft.

C. CONCLUSION

Both manned and unmanned aircraft have advantages. Manned aircraft provide a reliable means in putting Airmen in the battlespace providing better overall situational awareness and decision-making capability. Significant improvements in maneuverability and defense systems have also increase mission survival rates reducing the cost in human life as well as replacement aircraft costs. Finally, the use of manned systems keeps in check the desire to use military force as a means of policy enforcement based on weighing the human costs to warfare. In contrast, unmanned aircraft have the benefit of remote control completely eliminating the potential for casualties. In addition, the physiological and design limitation imposed by having pilots in the aircraft suggest that the removal of the pilot improves performance while at the same time reduces costs.

While there is no question that procurement costs are significantly less for UCAVs than the F-22, it is difficult to make an overall cost comparison. A lack of current data on UCAV life cycle cost components combined with current measurement methods might not accurately reflect the total costs of UCAV weapons programs. Current UCAV systems while in expensive to procure are shifting costs from areas such as fuel and maintenance to personnel costs associated with the 140 operators and analysts required per operational orbit stated earlier. In addition, the satellite communication costs are difficult to assess based on multiple users sharing the costs of procuring these advances space systems. In closing, the lower price tag on current UCAVs is appealing but is most likely a product in reduced capabilities calling into question the impact to mission effectiveness.

[128] USAF UAS Factsheets.

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IV. AIRCRAFT EFFECTIVENESS

A. DEFINING THE ELEMENTS

The F-22 and UCAVs are military platforms designed for different primary missions but both important to Homeland Defense. The F-22 is an air dominance jet fighter designed to provide air superiority for the foreseeable future at home and abroad while UCAVs discussed here are primarily instruments in information superiority and the current fight against terrorism. While both platforms also have the ability to employ air-to-ground munitions, this capability is considered more of a force multiplier than a primary role. Because these aircraft differ so widely, it is important to use fundamental elements to combat aircraft effectiveness to legitimize the comparison. The elements used to evaluate these two systems are reliability, survivability, availability, and versatility. These measures of effectiveness determine the worth of an aircraft to the USAF and homeland defense. While all four elements are important to the effectiveness of an aircraft to accomplish its mission, the threat environment decides which elements take priority over the others.

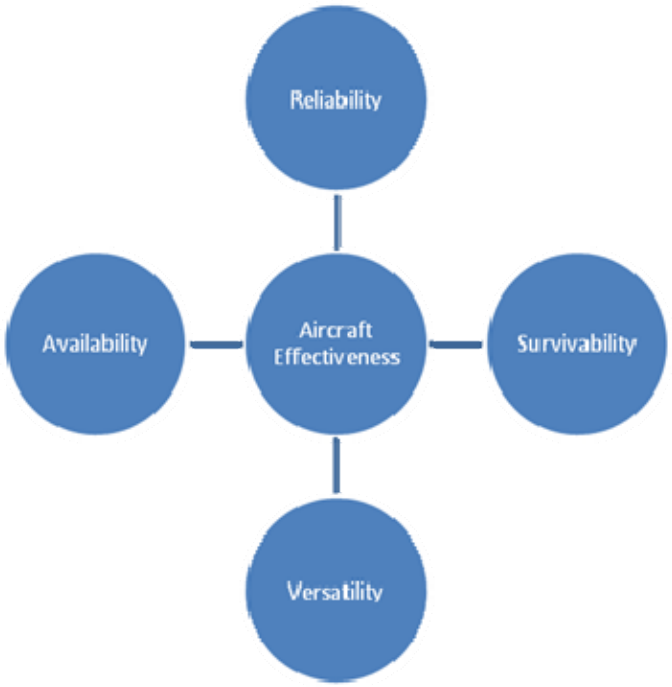

Figure 12. Measures of Aircraft Effectiveness.

The first measure of aircraft effectiveness evaluated is reliability. Achieving mission objectives starts with making it to the fight. The elements of reliability that are compared deal with maintenance factors, mishap rates, and vulnerabilities. The USAF uses information such as mean time between maintenance (MTBM), direct maintenance man-hours per flying hour, and mission capable rates (MCR) to help define the reliability of a given platform.[129] Mishap rates are another measure used to show reliability of a platform. Class A mishaps are defined as "an accident that results in fatality or total permanent disability, loss of an aircraft, or property damage of [$1M] or more."[130] To qualify mishaps as related to aircraft reliability to perform the mission, the incidences will be limited to those that completely destroy the aircraft preventing its ability to accomplish the mission. Lastly, reliability is assessed by identifying vulnerabilities limited to dependencies that are unique to each platform. If theses associated systems or capabilities are unavailable or disrupted, it will render the platform essentially useless. An aircraft that is easy to fix, is able to fight the next day, and has limited vulnerabilities makes for an effective weapon system.

The second measure used to evaluate these systems is survivability. Being able to survive the battlefield and comeback the next day significantly adds to the appeal of a weapons system. The primary elements discussed are aircraft performance, defensive systems, and system redundancies. USAF aircraft must be able to perform the mission in a wide range of environments. Aircraft performance such as speed, altitude and maneuverability all play a role in completing the mission and making it back to base. In addition, defensive systems give an aircraft the ability to know when they are either approaching danger or are being targeted adding to its ability to avoid these high risk situations. In the inevitability of war, aircraft will inevitably take battle damage. Aircraft system redundancies aid in the safe recovery to base adding to overall effectiveness of a platform.

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[129] Ronald O'Rourke, *Air Force F-22 Fighter Program*, 36.

[130] USAF Judge Advocate General (JAG) Corps, http://usaf.aib.law.af.mil/AIB_Info.html (accessed 20 October 2009).

The third measure of aircraft effectiveness is versatility; the ability of a platform to perform effectively across a wide range of requirements. Each system is evaluated based on the variety of mission sets, areas of operation, and payloads that characterize each platform. The multitude of mission sets an aircraft can perform adds to its applicability and usefulness to the USAF. Homeland Defense has many aspects both within the U.S and overseas; the ability to perform in many areas of responsibility (AOR) is a necessary capability and saves duplication in spending. Lastly, each platform is looked at for its ability to carry a variety of weapons and sensors making the aircraft more versatile. Weapon systems that are capable of performing a wide range of missions, operate in different AORs, and carry a variety of payloads best exemplify the versatility element of effectiveness.

The last measure of effectiveness is availability; when the President or theater commander makes the call to employ a weapon system these factors significantly contribute to the decision. The elements to availability include; overall numbers of aircraft to accomplish the mission, support requirements to get the aircraft into the fight, and aircraft capabilities such as range, endurance and speed. The theater commander must have access to the number of aircraft required to accomplish a specific mission. Part of this equation relies on the support requirements such as personnel, airlift, and forward locations capable of supporting the aircraft when taking the fight to the enemy. The aircrafts capabilities such as range, endurance and speed are also important with respect to time aspects of availability.

While making each one of these elements of equal importance could be justified, the threat environment significantly influences the importance of each element of effectiveness. To address the spectrum of threats these systems might face, three threat levels are discussed; low, high, and unknown or unpredictable threat environments. The low threat environment would be similar to the current situations in Afghanistan and Iraq where the enemy has little air defense assets significant to disruption of air power. The high-threat environment possesses an Integrated Air Defense System that is specifically designed to defend against an enemy Air Force. China, Russia, N. Korea, and Iran would be considered high-threat environments. The last scenario is the unknown or

unpredictable threat environment. This can be looked at in two ways; either the intelligence reports do not understand the capabilities of the enemy forces or its unknown whether or not the host country would employ these capabilities against U.S. aircraft. Consider the continuing war on terror and efforts to capture international terrorist within states that are not necessarily friendly to the U.S. There would most likely be a diplomatic agreement between the U.S. and the host country but it is difficult to predict what would transpire if there is a perceived misuse of the freedom to operate within the borders of this sovereign territory. This would be similar to our current UCAV operations in border areas of Pakistan.

B. F-22 EFFECTIVENESS

The F-22 is the world's most advanced air-to-air combat aircraft; it combines stealth, extreme maneuverability, and integrated avionics to provide air dominance in defense of the U.S. and its interests. While the F-22 was originally designed to replace the aging F-15, the shrinking role of air-to-air combat after the collapse of the Soviet Union suggested the addition of other capabilities, such as air-to-ground employment to justify its continued development.[131] Questions still remain regarding continued funding of the program. It is true that the F-22 has not participated in recent conflicts; but judging a platform on its worth, based on one form of warfare, does not adequately evaluate the effectiveness of the platform. This section will address the F-22s effectiveness in homeland defense by applying the four elements previously defined. This evaluation will give a more rounded view of the F-22 and its ability to effectively provide homeland defense, regardless of the enemy.

1. Satisfying the Elements

The reliability and maintainability of the F-22 has been called into question by reports citing increases in maintenance required per flight hour instead of decreases as the system matures and MCRs as low as 55%.[132] To refute these claims, the USAF provided

[131] O'Rourke, *Air Force F-22 Fighter Program*, 1–2.

[132] Ibid., 28.

maintenance data to clarify reports. The F-22 requirement for maintenance hours per flight hour is 12.0 at system maturity defined by a fleet wide 100,000 hours which is expected in late 2010.[133] In 2008, this number was 18.1, down from 30 hours in 2007 and most recently the number has dropped to 10.48 in 2009.[134] Provided the F-22 maintains this level of reliability, it will have met the USAF requirement ahead of schedule. In addition, the MCR for the F-22 has improved from 62% in 2004 to 68% in 2009 and is considered well within normal rates for this stage of operations.[135] In the area of mishap rates, the safety designs of the F-22 have proved fruitful. During its five years of operational flying, the F-22 has had no class A mishaps resulting in a loss of the airplane. Two class A crashes, one in 2004 and another in 2009 occurred during test missions and were test aircraft and subsequently do not reflect the reliability of the operational F-22.[136]

Survivability is one of the F-22's main advantages. Performance characteristics of the F-22 such as Mach 2 speed combined with unmatched turn rates and maneuverability with the use of thrust vectoring make it difficult to knock out of the sky by enemy aircraft.[137] Sustained supersonic speed at altitudes above 50,000 feet drastically reduces the ability of surface-to-air missile systems to track and engage the F-22.[138] Integrated avionics which employ both offensive and defensive systems to provide the pilot with exceptional situational awareness accentuate the advantage of surprise and increase survivability.[139] Probably the most influential aspect of the F-22 pertaining to survivability is its advanced stealth technology. "Lose sight, you lose the fight," a common vernacular in the air-to-air combat world best describes the advantage of low observable technologies relating to radar, infra-red, and visual spectrums. It is very

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[133] Air Force Association (AFA), "F-22 Assertions and Facts," http://www.afa.org/edop/2009/edop_7-13-09.asp, (assessed 21 October 2009).

[134] O'Rourke, *Air Force F-22 Fighter Program*, 34–36.

[135] Ibid., 33.

[136] USAF JAG Corps.

[137] USAF F-22 Factsheet, http://www.af.mil/information/factsheets/index.asp, (accessed 25 May 2009).

[138] Ibid.

[139] Ibid.

difficult to engage and destroy a system that you do not see. And lastly, aircraft system redundancies like two engines, triple redundant flight control systems, and robust secondary and tertiary electronic systems aid in the F-22s ability to withstand battle damage and effectively return home to fight another day.

The versatility inherent to the F-22 includes the dominance in a wide range of Homeland Defense missions. The F-22 is fitted with systems to detect enemy aircraft, employ air-to-air missiles, and destroy the adversary before they can counter the attack. This capability is essential in both offensive and defensive counterair operations and applies both within the U.S. and when protecting U.S. assets overseas. Additionally, Lt Gen. Harry Wyatt, Director of the Air Nation Guard (ANG) identifies cruise missile defense as a unique capability the F-22 provides in Homeland Defense.

> While a variety of solutions abound, I believe the nature of the current and future asymmetric threats to our Nation, particularly from seaborne cruise missiles, requires a fighter platform with the requisite speed and detection to address them. The F-22's unique capability… enables it to handle a full spectrum of threats that the ANG's current legacy systems are not capable of addressing.[140]

The F-22 is a key enabler in the Global Strike Task Force. Providing Air Dominance so U.S. joint forces can operate without the threat of enemy air forces is vital to overall mission success. Suppression of enemy air defenses, or SEAD, is another mission capability of the F-22. Combining the F-22's speed and high altitude capabilities it can target enemy ground based air defense systems with its GPS guided joint direct attack munitions (JDAM). The ability to carry both air-to-air and air-to-ground munitions internally allows the F-22 the flexibility of airborne re-tasking even in a high-threat environment. When designed against the most capable surface to air threats, it is safe to say the in either an unknown or low threat environment, the F-22 can perform as well if not better than in the high-threat environment. The question is whether or not the airspace is defended by an adversary. As former commander of Air Combat Command, General Corley has said, "Everybody has figured out that airpower—specifically, from

[140] Lt Gen. Harry M. Wyatt III to Senator Saxby Chambliss, 9 July 2009, http://www.airforce-magazine.com/SiteCollectionDocuments/Reports/2009/July%202009/Day09/Wyatt_to_Chambliss.pdf (accessed 19 September 2009).

the U.S. Air Force—is America's asymmetric advantage."[141] It isn't that the F-22 does not have the capability to engage in the war on terror, it is that the use of this system is unnecessary and an inefficient use of valuable resources. There is no threat to air superiority in either Iraq or Afghanistan, and the cost to employ the F-22 in the air-to-ground role does equal the advantage gained.

The last measure of effectiveness used to evaluate the F-22 is availability. The Raptor is strategically based throughout the U.S. for rapid response to possible threats and provides in-place support facilities for force build up when required. Deployments to locations in the Pacific such as Andersen AB, Guam and Kadena AB, Japan provide prove that the F-22 is worldwide deployable.[142] The F-22 requires the same runway requirements of legacy fighters and can deploy will much less airlift than current fighter aircraft reducing the logistical strain. In addition, year round operations in Alaska add cold weather operations to its "all-weather" capability. Probably the most important characteristic to availability for the F-22 is supercruise. The F-22 has the unique ability to maintain supersonic flight without the use of afterburner. This significantly increases the F-22s ability to cover great distances quickly while still having enough fuel to conduct operations once it reaches its destination. This has two advantages to the theater commander; first, it reduces the required lead time necessary to accomplish the objective and second, fewer assets are required per volume of airspace allowing for greater coverage or replacement capability. While all of these characteristics suggest the F-22 is the greatest aircraft ever built, it also has limitations that impact its overall mission effectiveness.

2. Challenges to F-22 Effectiveness

While the F-22 has proven to dominate the skies in many combat exercises, issues involving maintainability of the F-22 have surfaced questioning its true reliability. One such issue involves canopy coating problems. The designed service life of the coatings is

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[141] Rebecca Grant Ph.D., L*osing Air Dominance*, 4.

[142] Air Force News Service, "F-22 Scheduled to Deploy to Japan, Guam," http://www.af.mil/information/transcripts/story.asp?storyID=123128379 (accessed 3 September 2009).

800 hours but current canopies require recoating at approximately 330 hours.[143] The USAF acknowledge this current limitation but suggests with new contracts and improved coating techniques the canopy life spans will continue to increase but are still well below the requirement. Other claims suggest the stealth coating used on the F-22 is defective. Darrol Olsen, a former Lockheed Martin engineer who worked on the program, claims that the company knowingly used substandard materials in the F-22s stealth coatings.[144] While these reports remain unsubstantiated, there is one incident involving a large piece of low observable material that separated from and F-22 and was subsequently ingested by an engine.[145] The incident caused approximately $1.2M in damage to the right engine. The findings site the use of C493 as a contributing factor to the mishap. C493 was identified as a deficient material by the manufacturer for its cohesive strength and was replaced by a different material in later production aircraft. Unfortunately, 30 aircraft still operate with this material, but maintenance personnel have developed techniques to identify possible failures in hopes of mitigating this issue.[146]

Probably the most critical vulnerability to the F-22 is its dependence on in-flight refueling. While its combat radius is classified, the published ferry range is 1600 nautical miles, without refueling, which includes the use of two externally mounted fuel tanks.[147] In a combat configuration the F-22 can carry approximately 18,000 pounds of fuel internally, and with engines capable of producing a total of 70,000 pounds of thrust, the potential to quickly empty its fuel reserves is of real concern.[148] In-flight refueling can extend the F-22s ability to cover its AOR but is limited in range in high-threat environments due to the non-stealth tankers. While these issues do not apply in homeland defense missions where the threat is minimal and the transitory distance is

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[143] O'Rourke, *Air Force F-22 Fighter Program*, 36.

[144] Sam LaGrone, "F-22 Maker Accused of Fraud in Lawsuit," http://www.airforcetimes.com/news/2009/07/airforce_F22_lawsuit_070209/ (accessed 10 October 2009).

[145] USAF Abbreviated Accident Investigation Report, http://usaf.aib.law.af.mil/F-22A_Nellis_2Nov07.pdf (accessed 10 October 2009).

[146] Ibid.

[147] F-22 Factsheet.

[148] Ibid.

small, the limited number of F-22s would require multiple handoffs between formations covering the AOR. An enemy's ability to deny tanker support close to the battlespace seriously limits the F-22s effectiveness.

Stealth technology is the signature survivability characteristic of the F-22. Techniques against active radar searching, IR/EO sensors, passive listening systems and even visual identification are all used to enhance the Raptor's ability to remain unseen by adversaries. Even though the F-22 is designed to combat most target acquisition and tracking radars, the aircraft is not completely invisible. A passive radar using bistatic ranging has the potential to counter stealth-based airpower.[149] By networking transmitting and receiving systems that are not co-located it is possible to triangulate the location of the stealth aircraft. In addition, measuring the Doppler shift of the wavelength can determine the heading and speed of the aircraft necessary for tracking.[150] The combination of low cost and off-the-shelf technology makes these systems and appealing attempt at countering stealth technologies. Application of such techniques while possible would require large quantities of transmitters and receivers throughout an AOR and networking of all the systems to continually track the target. In sparsely populated areas, this would be a minimal threat, but in government control metropolitans, the potential exists for passive radar tracking.

Probably the most recognized challenge to F-22 effectiveness is its absence for the current conflicts in Iraq and Afghanistan, due in part because of timing, but mostly because of current applications of airpower in these conflicts. The F-15 deployed in support of Operation IRAQI FREEDOM (OIF) in 2003 to ensure air superiority and unimpeded operations to myriads of allied aircraft and ground forces.[151] Delaying this action until 2005 would have put the F-22 in combat silencing the claims of its inapplicability to the conflicts. While the F-22 can perform a wide variety of missions to

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[149] Arend G. Westra, "Radar versus Stealth: Passive Radar and the Future of U.S. Military Power," *Joint Forces Quarterly*, 55, 4th quarter, 2009, 139.

[150] Ibid., 139–140. Doppler shift is defined as wavelength compression or expansion caused by relative motion.

[151] 1st Fighter Wing Public Affairs Office, *Langley Home of 1st Fighter Wing,* http://www.af.mil/news/story.asp?id=123031184 (accessed 20 October 2009).

include CAS, the lack of additional sensors such as an infrared or electro-optical targeting pod or helmet mounted site for designating targets makes this capability limited at best. Combining these limitations with the estimated cost per flight hour of approximately $45k and the cost-benefit analysis for using the F-22 over other systems seems foolish unless the threat environment was so extreme that it was the only asset capable of accomplishing the mission.

Availability is most likely the biggest challenge to F-22 effectiveness. In 1974, before the F-22 was picked to replace the F-15, the USAF wanted a one-for-one replacement ratio for the F-15, which would require 750 air superiority fighters.[152] The end of the cold war and other subsequent force restructuring reduced the desired number to 339 in 1997. In 2005, the number was further cut to an end production quantity of 179.[153] Adding eight aircraft designated as test vehicles the USAF will have 187 F-22 aircraft at production completion in 2011.[154] While this number is significantly less than originally desired by the USAF, senior military officials believe it is more than enough to satisfy both homeland defense requirements as well as possible future conflicts abroad. When subtracting the eight test aircraft, 30 training aircraft for basic and weapons school programs, and applying the MCR of a generous 70%, the F-22 operational fleet is reduced to 104 aircraft. While this seems like a significant number, when required to provide 24-hour coverage of an AOR this number becomes very small. Assuming a homeland defense mission where transit time to the AOR is negligible, and applying standard four ship formations covering an aggressive 200 miles of coastline, it would require approximately seven formations, or 28 aircraft to cover the east coast at once. Including spare aircraft, this breaks down to three waves of four ship formations per day requiring each to stay airborne for eight hours for continuous coverage. This is well beyond the F-22s unrefueled employment capability. This is a rather simplified example, but it establishes how quickly total force numbers become small when applied to an

[152] Thomas W. Hampton, *The Quest For Air Dominance: F-22—Cost versus Capability* (Maxwell AFB, AL: Air Command and Staff College, 1998), 27.

[153] Ronald O'Rourke, *Air Force F-22 Fighter Program*, 6–7.

[154] Ibid.

operational scenario. The counter argument though states that scenarios such as this are either non-existent or the layered defense systems provided joint military operations would be sufficient to counter such a threat and there are more important deficiencies in the USAF applicable to conflicts of today.

C. UCAV EFFECTIVENESS

Since its start in 1995, the MQ-1, and its recent spawn the MQ-9, has seen a rapid increase is operations. Currently, the USAF operates 34 CAPs in Iraq and Afghanistan—almost triple from the 12 in 2006 and plans to increase that number to 50 by 2011.[155] These UCAVs have become the primary focus of the USAF in the fight against terrorism.[156] While these systems are solving a deficiency in asymmetric warfare, what is the opportunity cost? With the F-22, it was vast amounts of money concentrated away from the current conflict,—what do we give up by concentrating on these systems? This section covers how UCAVs satisfy the elements of aircraft effectiveness and what challenges are introduced by relying on these platforms to complete critical missions across the full spectrum of conflicts.

1. Satisfying the Elements

When it comes to maintainability, the Predator and Reaper have remarkable track records. The simplistic design makes for quick maintenance checks and when systems do break, the time to fix the problem is usually short compared to more complex aircraft. Most of the maintenance performed on the MQ-9 is not due to parts failures, but for time-change orders.[157] On systems as new as the MQ-9 that have not completed their test phase, parts are routinely replaced to collect data, which will eventually allow for longer times between changes. So far, the MQ-1 and MQ-9 has performed well when it comes to maintainability. In a report done in 2008, the MQ-1 MTBM was calculated at an amazing 77 hours due in part by the duration of each mission but still an example of

[155] Christopher Drew, *The New York Times*, 17 March 09.

[156] Ibid.

[157] Tirpak, *Rise of the Reaper*, 37.

significant reduced maintenance work.[158] While the Predator has had a rather poor Class A mishap rate over its 14 years in service that will be addressed later, many improvements have been made on the next generation MQ-9 and thus far have paid off. While there have been two operational Class A mishaps only the most recent on Sep 13, 2009 resulted in the loss of the aircraft.[159]

Survivability is not a primary design factor, but only a handful of UCAVs have been shot down in combat. They might not be the fastest or most maneuverable aircraft in the sky, but they do possess capabilities that enhance survivability. Most threats in the current war on terror are altitude limited, such as shoulder fired MANPADS and small caliber artillery, allowing UCAVs the ability to overfly potential danger.[160] In addition, operating above 25,000 feet means the aircraft is very difficult to hear and almost impossible to see with the naked eye employing natural "stealth" elements.[161] Even when at lower altitudes, the Predator is considerably smaller than standard military aircraft making it difficult to find in the sky. The Reaper has a generous wingspan of 66 feet, but the slender design of the wings and fuselage make difficult to see as well but has advances ISR sensors enabling it to maintain higher orbits.[162]

The most influential factor to the overall effectiveness of UCAVs has to be their versatility. Their contributions in Iraq and Afghanistan are well documented in the war on terrorism. With operational endurance between 18–22 hours, Predator or Reaper systems can accomplish multiple different missions over the course of one sortie to include: "[ISR], CAS, combat search and rescue support, precision strike, buddy laze,

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[158] Dr. Ernest Seglie, "Investing in Reliability, Availability and Maintainability & the Effect on Logistics, Operational Support, and Life Cycle Cost," http://www.gardenstatesole.org/events/symposium08/seglie.pdf (accessed 10 October 2009), 18.

[159] Sean Gallagher, "Military under the Gun on Unmanned Aerial System Mishaps," *Defense Systems*, October 2009, 38.

[160] MANPADS are man-portable air defense systems that are widely distributed, inexpensive and easy to operate.

[161] USAF UAS Factsheet. The operational ceiling of the MQ-1 is 25,000 feet while the MQ-9 can operate up to 50,000 feet.

[162] Ibid.

convoy or raid overwatch, target development, and terminal air control."[163] While the Predator is limited to carrying two hellfire missiles, the Reaper is designed to carry a combination of hellfire missiles, JDAMs, or laser guided bombs significantly increasing its capabilities. The sensors carried by these systems provide imagery, full motion video, and signal intelligence (SIGINT) collection for intelligence personnel to analyze and provide to combatant commanders. However, commanders do not have to wait for analysis, current UCAVs can provide data simultaneously to over 12 locations significantly enhancing SA in the process.[164] UCAVs can also be used as a communications relay adding to their versatility. Putting a communications antenna over the battlefield continuously does a couple things; one, it reduces the demand on satellite resources free up space for other systems including UAVs and two, it offers a solution to line-of-sight issues where ground based radios are blocked by terrain.[165] Both of which are significant factors in the war against terrorism in Afghanistan.

In addition to these combat roles, they also provide persistent eyes in the sky in support of homeland security missions, such as border patrol and disaster response. While the United States Border Patrol (USBP) currently operates its own Reaper (Predator B), additional UAVs could be obtained through U.S. Northern Command (USNORTHCOM) in times of need. The increased range, endurance and thermal detection capabilities of the UAVs over that of current stationery equipment or manned aircraft make UAVs an attractive asset to USBP.[166] Events like Hurricane Katrina, or the various California wildfires, represent ideal cases for the use of persistent UAV coverage. Searching for individuals in need of rescue or monitoring progression of a fire require continuous operations falling into the "dull, dirty, or dangerous" considerations in using UAVs.

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[163] Headquarters Air Force, *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047*, 2009, 26–27.

[164] Lt Gen David Deptula, *ISR - Precision Strike Capabilities & Technology Improvement*, http://www.dtic.mil/ndia/2008psa_psts/Deptula.pdf (accessed 10 October 2009).

[165] David F. Carr, "Communications relay grows with expansion of UAV missions," *Defense Systems*, August 2009, 28.

[166] Christopher Bolkcom, *Homeland Security: Unmanned Aerial Vehicles and Border Surveillance*, (Washington, D.C.: Congressional Research Service, 13 May 2008), 3.

Another significant factor contributing to the overall effectiveness of UCAVs is that of availability. UCAVs discussed here are small, portable, and require very little in support hardware. Each air vehicle can be disassembled and packed into a crate that fits in a C-130, C-5, or C-17 cargo aircraft. To deploy enough parts and personnel for one CAP, it requires five C-130s to carry "four air vehicles, a GCS, support equipment, a Trojan Spirit II van, and 65 personnel."[167] This complete deployment package allows sustained 24/7 operations for 30 days.[168] The savings in logistical support requirements comes from the ability to control a significant portion of the mission from home station thousands of miles away. Deploying one GCS to support a squadron's takeoffs and landings saves considerable space and forward support. In addition to the smaller "footprint," these UCAVs require only 5,000 feet of runway and the absence of a jet engine reduces Foreign Object Damage potential at deployed locations.[169] In comparison, most manned fighter aircraft require a minimum of 8,000 feet and arresting gear incase of breaking problems.

Currently, the Air Force has 130 Predators and 10 Reapers.[170] Theater commanders have 34 CAPs at their disposal in Iraq and Afghanistan combined and the desire to reach 50 by 2011. While this seems like a lot of orbits, this increased number will cut reaction time in half providing ground troops airborne ISR and weapons before the situation changes. These added CAPs are one more example of the persistence needed when fighting an elusive enemy like Al Qaeda. Another aspect of availability, endurance, is a huge advantage UCAVs have over manned aircraft. The ability to maintain a constant watch over an area, without the need for air-refueling or constant changeover due to fatigue, greatly reduces support requirements and provides constant coverage to build an accurate intelligence picture. Having persistent ISR assets with the

[167] ACC, "UAS Concept Of Operations", December 1996, http://fas.org/irp/doddir/usaf/conops_uav/part03.htm (accessed 12 August 2009).

[168] Ibid.

[169] Ibid.

[170] USAF UAS Factsheet.

capability to release weapons also significantly reduces the time it takes to engage a target once it has been identified. While UCAVs have proved effective to combatant commanders, they are not without their faults.

2. Challenges to UCAV Effectiveness

While maintaining UCAVs is simplistic compared to manned aircraft like the F-22, and the time between fixes is drastically longer, the long flight times increases their susceptibility to failures as evident by their Class A mishap rates over the time in service. As mentioned earlier, the Reaper seems to be doing better than the Predator, but this is in part due to the relatively short amount of flight hours, as compared to the Predator. Sixty-Five of the 195 purchased have been lost in Class A mishaps including 13 in the last 18 months.[171] Class A mishap rates are not measured in real terms but in number per 100,000 flight hours. The Predator accumulated approximately 600,000 hours over this same timeframe producing a mishap rate of 10.8. Even considering test aircraft, and the fact that the F-22 has not reached 100,000 hours, its rate is approximately 4.0.[172] Whether the cause of the crash was maintenance, datalink loss, or human error the end result is one less UCAV.

A unique dependency to UCAV operations is its reliance on Datalink. UAVs operate both within line of sight and beyond line of sight (BLOS) with the use of satellites. The current construct uses an in-theater GCS to launch and recover the vehicles but uses satellite relays to control the UAV during tactical employment. This operational setup reduces the forward deployed footprint that is vulnerable to enemy attack and reduces the potential for casualties but highlights potential critical nodes to mission accomplishment. The reduction in GCS facilities makes for a more cost-effective way to recover the UAVs, but if destroyed or rendered useless through jamming, it would put the recovery of the aircraft in jeopardy. Another aspect to UAV control that is vulnerable to exploitation is the datalink. Effective jamming of either the

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[171] USAF JAG Corps, "Mishap Reports," http://usaf.aib.law.af.mil/ (accessed 20 October 2009).

[172] Ibid. The F-22 passed 50,000 hours in Aug 08 and a rate of 4.0 assumes double the actual number of aircraft lost to Class A mishaps.

uplink or downlink would make the UAV ineffective in providing the FMV to tactical forces and the AOC. Finally, the satellites themselves become critical nodes when a single satellite is used to control a significant number of combat assets such as UAVs. China showed it is possible to take down a LEO satellite with an ASAT interceptor missile when they destroyed an aging weather satellite in January 2007.[173] Additionally in September 2006, China fired a ground-based laser at a U.S. Optical reconnaissance satellite in order to prevent pictures being taken overhead.[174] Though currently dependent on satellite communications for BLOS operations, the USAF looks to move away from this dependency. The plan involves using a tactical data link system between airborne, ground, and maritime assets.[175] It is important to note that this is not a current capability and is seen as a desire to reduce this acknowledged dependency on SATCOM.

Despite claims about UCAVs being able to outperform manned aircraft, the current systems are built for persistence not maneuverability and have posed no threat to enemy fighters while at the same time been easy targets.[176] The max speeds of the MQ-1 and MQ-9 are 120 KIAS and 240 KIAS respectively and are designed for fuel efficiency not maneuvering speed.[177] Additionally, while the max altitude of the Predator is 25,000 feet, it is best employed between 10,000 and 20,000 which is in the heart of the engagement zone for a significant number of surface-to-air missile systems. The Reaper adds survivability by operating between 25,000 and 30,000 but at such slow speeds at this altitude the Reaper has to rely solely on overflying the threat.[178]

Another aspect of survivability that manned aircraft rely on is the combination of visual lookout and defensive warning systems built into the aircraft. Having a pilot in the cockpit offers 360 degrees of scanning, and the warning systems narrow the search volume for easier visual pick up of a missile in flight or at launch allowing the pilot apply

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[173] Karl Ginter, *Space Technology and Network Centric Warfare: A Strategic Paradox* (Carlisle Barracks, PA: U.S. Army War College, 2007), 7.

[174] Ibid., 8.

[175] USAF, *UAS flight plan 2009-2047* (Washington, D.C.: HQ Air Force, 2009): 43.

[176] David A. Fulgham, "Predator's Progress," *Aviation Week and Space Technology*, March 2003, 48.

[177] USAF, *UAS flight plan 2009-2047*, 26–27.

[178] Ibid.

defensive reactions dramatically increasing survivability. Current UCAVs must use their sensors to try and accomplish the same thing. The Predator has a field of view of only 120 degrees and does not possess any warning systems within the aircraft making defensive reactions almost impossible.[179] In addition, the absence of countermeasures such as chaff and flares also reduces a UCAVs ability to survive if engaged by air defense systems.[180] Other aspects to UCAVs, such as having one engine and minimal system redundancies other than flight controls, suggest they are built for cost efficiency and not survival. Why spend extra money on redundancies when they are suppose to be expendable, a common mindset in UCAV development. Without a human life at stake, the need for defensive systems also seems to be a waste of time. While there is no loss of life, if a UCAV is destroyed the impact to mission success is significant. Current UCAVs are dependent on other aircraft, life the F-22, to provide an air superiority blanket and a minimal surface to air threat in the operational AOR for their survivability.

As discussed earlier, UCAVs have incredible versatility in mission accomplishment, but significant hurdles must be crossed before they can be effectively employed in all of them. The main problem to implementation is deconfliction. The battlespace over Iraq and Afghanistan have become congested making midair collisions more prevalent. A mid-air collision occurred in Iraq involving a smaller Raven UAV and a helicopter and a near-miss also occurred in Afghanistan between a German military UAV and an airliner on final approach to Kabul.[181] Most UCAVs are equipped with transponders giving aircraft with interrogation capability the ability to search for and then avoid UCAVs, but most aircraft do not have this capability, especially civilian aircraft. To employ effectively in Homeland Security and Defense roles within the U.S. National Airspace System (NAS) the ability to "see and avoid" is paramount. Current UCAVs do

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[179] Kevin L. Digman, *Unmanned Aircraft Systems in a Forward air Controller (Airborne) Role*, (Maxwell AFB, AL: Air Command and Staff College, 2009), 11.

[180] Chaff is used against radar guided missiles and enemy radar systems in an attempt to break the radar lock or confuse the radar enough to defeat the intercept. Flares are designed to appear hotter than the original target aircraft drawing a heat-seeking missile's sensors away and thus saves the aircraft of the impact.

[181] Barry P. Leister, *Time for Centralized Control of Unmanned Aerial Systems*, (Carlisle Barracks, PA: U.S. Army War College, 2007), 6.

not have systems that can detect other aircraft or obstructions and then safely maneuver to avoid a collision.[182] In addition, these systems must be able to detect aircraft that are not equipped with transponders that identify their location electronically.[183] In essence, UCAVs will have to possess either a radar system or optical device that will inevitably add weight and significant cost to implement and until then civilian airspace use will be limited.

While extended loiter time is a major advantage to UCAV availability, the personnel numbers to fly the systems and analyze the data are slow to meet the demand. The increase in ISR operations has been a staggering 1,431% with respect to hours with the majority being Predator and Reaper.[184] The training unit increased throughput from 129 to 164 crews but 76 of these crews were ANG or special operations crews leaving a shortage of approximately 100 pilot positions.[185] The USAF does not have the infrastructure of operators and analysts to effectively operate the amount of ISR orbits desired by senior military leaders. To try and meet this added personnel demand the USAF requested "to increase MQ-1 Predator, MQ-9 Reaper, and Distributed [CGS] operational capability to 50 Combat Air Patrols [by funding] 4,100 military positions."[186]

D. PRIORITIZING IN RELATION TO THE THREAT

Versatility adds greatest to your worth, minimal risk so survivability is low on the list. Availability is important because these environments are more predominant since it doesn't take a lot of money or resources to start a conflict that is low threat. Getting the system to the Warfighter is more important in helping win the fight than having the most reliable platform. Many times Sec. Gates has stated it is more important to get the "75

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[182] Matthew T. DeGarmo, Issues Concerning Integration of Unmanned Aerial Vehicles in Civil Airspace, (McLean, VA: MITRE Corporation, 2004), 2–3.

[183] Ibid.

[184] HAF/A9, *Enduring Airpower Lessons From OEF/OIF: UAS Predator/Reaper Surge Operations*, (Arlington, VA: HQ Air Force, 2008), 1.

[185] Ibid.

[186] Lt Gen Richard Y. Newton, III, *Air Force Military Personnel Budget Overview*, http://armedservices.house.gov/pdfs/MP052109/Newton_Testimony052109.pdf (accessed 10 October 2009), 2.

percent solutions over a period of months" than to wait until all the issues have been vetted.[187] UCAVs provide the elements of effectiveness that thrive in this environment. The systems apply to a wide variety of mission sets important to homeland defense and security both at home and abroad in the war on terror. The ability to provide persistent eyes on the objective whether it be a terrorist, wildfire, or national border, substantially increases the probability of success and enhances SA.

In contrast, survivability is the most important measure within a high-threat environment. Getting to the AOR with a myriad of capabilities makes little difference if you are destroyed before reaching your target. With this in mind, reliability become a close second for similar reasons. In a high-threat environment, every mission is critical making re-attacks because of aircraft malfunctions extremely costly. High-threat environments also put a strain on external dependencies; the more self-reliant a system is the better chance of success in highly defended AORs. A commander will choose a weapon system they have the utmost confidence in, and trust that it will be ready on time and will accomplish the mission regardless of the defenses.

The final threat environment assessed is the unknown or unpredictable scenario. Typically in war it is important to assume that your enemy is fully operational in the capabilities you assess them to possess. Overestimating an opponent tends to have less impact in situations of actual combat when resources are at risk versus underestimating capabilities. The difficulty is in preparing for these conflicts. Overestimation can waste valuable time and money in preparing for an enemy that in actuality cannot produce a formidable defense. These uncertainties tend to force militaries into developing systems that are overqualified for employment in the eventual threat environment. Getting back to actual combat scenarios and measuring effectiveness, unknown or unpredictable threat environments will tend to put the same elements in priority than high-threat situations until better intelligence assessments are developed further into the conflict. In applying which elements to aircraft effectiveness would be most important in these types of threat environments it is important to look at it from the actual event and not a preparation stand

[187] Christopher Drew, *The New York Times*, 17 March 2009.

point. The debate as to whether or not a country has a capability or will imply it is moot, the real issue is whether or not the weapon system will complete its mission in the actual conflict.

E. CONCLUSION

To effectively defend the Homeland, the USAF must procure weapon systems that are reliable, survivable, versatile, and available. While low-threat environments characterize the current USAF combat missions, it is important to remember we cannot predict the future. Effective weapons systems have greater worth in homeland defense when they are employable across the full threat spectrum. In this light, the F-22 shows more applicability across this spectrum than current UCAV platforms. Table 2 provides a visual representation of how each system compares in the four measures of effectiveness. In general, conflicts between adversaries with the ability to impede free reign in the battlespace highlight significant limitations to current UCAVs directly affecting their ability to provide game changing persistent ISR to support ground forces and theater commander objectives. In contrast, current conflicts do not have these challenges making the versatility and availability of UCAVs more effective in low threat environments than the F-22.

	F-22			UCAV		
Threat Level	Low	Unk.	High	Low	Unk.	High
Reliability	XX	XX	XXX	X	X	
Survivability	XX	XXX	XXX	X		
Versatility	X	X	X	XX	XX	XX
Availability		X	X	XXX	XX	XX

Table 2. Effectiveness Comparison across Threat Spectrum.

Comparing the systems within each measure of effectiveness highlights this variable applicability. With respect to reliability, the edge goes to F-22s across the full

spectrum due to its lower mishap rate and limited external dependencies. UCAVs are simplistic in design and require less frequent maintenance but these advantages often lead to less reliable platforms reducing overall effectiveness. In missions supporting homeland defense and security, it is paramount that commanders can depend on the systems employed in all situations. The second measure of effectiveness, survivability, also gives the advantage to F-22s. The ability to defend itself with offensive systems and the combination of aircraft performance and warning systems significantly increase the probability that this system survives the mission. This should not be much of a surprise, and relates to protecting against the loss of human life. Inherent in the design of manned aircraft is the ability to bring the crew home. UCAVs do not have a pilot at risk releasing this design requirement. When there is no opposing threat, this allows for other optimizations and increases effectiveness in other ways but limits survivability. Current UCAVs have significant limitations beyond the low threat environment. The F-22 has the advantage in reliability and survivability but this trend changes when looking at the final two elements to mission effectiveness.

The combination of surveillance equipment and weapons employment significantly contribute to UCAV versatility giving it the edge in this element of effectiveness. The wide range of sensor types covers all aspects of information collection and gives UCAVs the ability to accomplish their mission regardless of external factors such as weather or time of day. In addition, the applications in times of peace such as border patrol and disaster response significantly adds to effectiveness in homeland defense and security, capabilities not associated with the F-22. The F-22 does have versatility with air-to-air and air-to-ground capabilities but its applications are limited. The F-22 is currently dependent on external sensors or platforms for any type of airborne re-tasking in relation to ground target destruction. The absence of sensors with the ability to locate moving targets significantly limits effective weapon employment in a dynamic battlefield. Even though UCAVs has limitations due to deconfliction requirements in congested airspace, the overall versatility UCAVs possess make it a more effective platform.

Availability is the final element of effectiveness evaluated and UCAVs have the edge in this area as well. Even though the current number of UCAVs is about the same as the F-22, the time it takes to build replacement UCAVs is significantly less than the 30-month production timeline or even the 12-month assembly process for an F-22 making UCAVs more readily available when the current quantity is not enough.[188] The logistical machine needed to forward deploy UCAVs, and the basic operating requirement at the forward location such as reduced runway length and support facilities, provide added incentive over previous manned fighters of which the F-22 is only slightly less imposing. While the F-22 maintains superiority in speed and range, when considering distance covered in a short amount of time, the endurance factor means commanders can count on UCAVs for persistent AOR coverage with minimal gaps contributed to aircraft handover.

In summary, this section evaluated the F-22 and UCAV systems using reliability, survivability, versatility, and availability as measures of effectiveness. The overall objective was to analyze the impact a movement toward UCAV procurement has on the USAFs capabilities in homeland defense missions across the entire threat spectrum. While versatility and availability factors favor UCAVs over F-22s, these elements are more important when the overall threat environment is low. In high or unknown threat scenarios, the reliability and survivability elements are more important giving the F-22 then edge in effectiveness. This analysis suggests a concentration toward UCAVs in future procurement while improving versatility and availability through a persistent presence reduces the USAFs effectiveness in defending the homeland across a broader spectrum of threat environments.

[188] Defense Industry Daily, "F-22 Raptor: Procurement and Events (updated)," http://www.defenseindustrydaily.com/f22-raptor-procurement-events-updated-02908/ (accessed 1 November 2009).

V. CONCLUSIONS

1. Twenty-First Century Defense Spending Influences on Acquisitions

On the one hand, through the National Defense Strategy, DoD has added an entirely new focus to warfare, that of irregular conflict, while trying to maintain our overwhelming dominance in conventional warfare. In addition, the Secretary of Defense has concluded that we also must be able to win at the full spectrum of hybrid warfare which is a myriad of combinations between conventional and unconventional conflicts. This would suggest we must continue to modernize our conventional forces to outpace any possible peer competitor while at the same time procure new assets that are better suited for unconventional conflicts. In the USAF, this means continued investment toward UCAVs while maintaining conventional dominance with major weapons systems like the F-22 and F-35. This will be no simple task, as DoD budgets are tight.

> The USAF has a significant challenge to deliver the required level of UAS capability based on a growing affordability problem for manned and unmanned systems. Specifically, operating costs, military personnel costs, and acquisition costs continue to escalate at a rate significantly higher than inflation.[189]

The USAF must balance acquisitions in a way that is best suited for its primary objective of homeland defense. With the current global climate suggesting a future decline in overall military burdens on economies but a significant rate increase on real expenditures by the principle peer competitors, now would appear to be a risky time to concentrate on the transformation in acquisition priorities. In trying to balance our focus between expensive conventional weapons programs and more economical UCAV systems for current conflicts, the USAF will most likely just shift spending instead of actually lowering the overall level of expenditures. While O&M costs for UCAVs are sure to prove cheaper than systems like the F-22, the added personnel costs will most

[189] *USAF UAS Flight Plan 2009-2047*, 68.

certainly trump those savings over the long haul. So while the per unit procurement cost savings seem large, it is the future force that will pay the price from today's short sighted fixes.

2. Advantages in Unmanned Flight not Completely Realized in Current UCAVs

While the first generation UCAV systems are less expensive than manned fighters, they are becoming increasingly indispensible. The loss of a UCAV saves the life of a pilot but blinds theater commanders who have become increasingly dependent on this information source. Improving reliability and survivability will come at a significant cost reducing the saving policymakers seem to be concentrating of today. Removing the physiological limitations of pilots to increase aircraft performance has yet to be developed in operational UCAVs. The current first generation UCAVs like the MQ-1 and MQ-9 are extremely limited in their performance capabilities. It seems like the only advantage these systems currently have is endurance when you compare airframes, but it will be interesting to see if future UCAV airframes will have the same endurance with the increased performance capability desired.

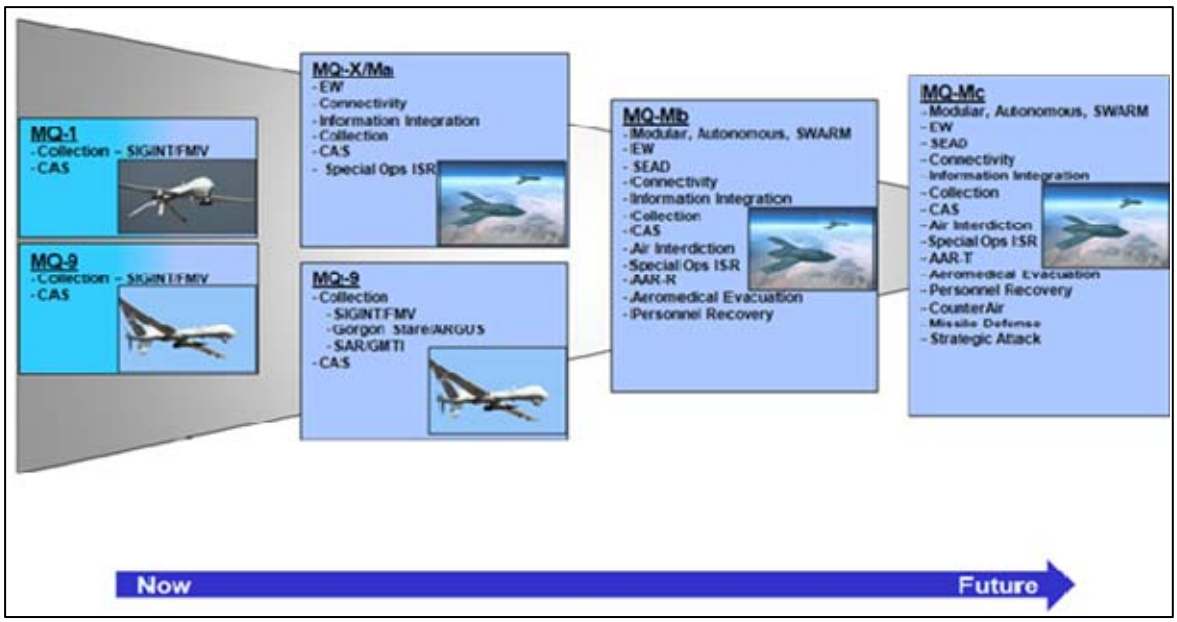

Figure 13. Evolution of the UCAV[190]

As technology progresses in UCAVs (i.e., X-47, X-45) the associated costs will also increase suggesting the money saved in procuring UCAVs employable in contested airspace are minimal and may even introduce greater vulnerabilities due to their dependence on satellite communications. So, where does that leave the USAF and its capability to provide an overwhelming force to defend the U.S. at home and abroad in the near term? They are left with a less effective aircraft fleet when charged with providing security against emerging global threats at all levels of warfare.

3. F-22 and UCAVs as a Zero Sum Game

While the F-22 provides air superiority in contested environments and paves the way for the rest of the combat aircraft to operate freely, including Predators and Reapers, there are many situations in Homeland Defense and Security that do not require this level of air dominance. Based on the trends in military expenditures throughout the globe, the potential for a high end conventional challenge to our homeland is minimal. While both Russia and China show signs of modernization, these capabilities are over a decade in the making. Right now our focus is on increasing our capabilities in the areas that have been

[190] *USAF UAS flight plan 2009–2047*, 38.

highlighted as weaknesses in our overall military, irregular warfare. The USAF contribution to this fight is UCAVs. While their overall effectiveness at providing airpower is less than the F-22s, the niche capability they provide is both necessary and beneficial to strengthening homeland security and defense in today's fight against violent extremists but what about tomorrow's fight? It is difficult to predict what type of threat to the Homeland the USAF will be called on to fight in the future but finishing second is not an option. While 179 operational F-22s seems like enough in conceivable scenarios today, it is difficult to predict what technological advancements will occur over the next decade. Shutting down the production line guarantees only one thing; the USAF will never have more than 179 operational F-22s. This will be the first time in over 35 years that the USAF will not have the ability to produce the world's leading air superiority fighters should the security environment change.

4. Transformational Mindset Increases Near-term Risk for Long-term Potential Gains

Closing the door on the most advanced defender of the homeland and moving toward advancements in UCAVs might increase risk in the near-term, but the general consensus of our senior leaders suggests it will pay long-term dividends in homeland defense and security. It is also concluded that while there are highly capable threat systems in the world today that the F-22 is uniquely able to counter, the likelihood of conflicts involving an overwhelming use of these systems to threaten U.S. sovereignty either directly or indirectly is remote. Balancing both capabilities and the potential use of combat weapon systems warrants the current reassessment in USAF acquisitions. Should a challenge present itself in the next decade that does require a significant F-22 presence, the level of risk imposed will be higher than desired but still within acceptable levels.[191] As mentioned earlier, Gen. Schwartz maintains that a force level of 243 F-22s would produce a moderate risk level based on operational plans for combating two simultaneous major conflicts. While this was the strategy laid out in the 2006 QDR, the new security environment supports a different strategy. The new strategy being drafted shifts the focus

[191] Rebecca Grant Ph.D., *Combat Air Forces in Crisis*, (Arlington, VA: Mitchell Institute Press, 2009), 5.

away from two simultaneous high-threat environments, or conventional wars, to one major conflict and a second hybrid scenario where irregular warfare and asymmetric threats dominate the battlespace. With this new strategy, Sec. Gates is confident the current 187 F-22s will be more than sufficient to manage any threat that might challenge our nation security at home or abroad. But to complete this strategy, an increase in procurement of systems like UCAVs is necessary to meet asymmetric challenges as well as build a foundation for future advance unmanned combat capabilities.

The previously mentioned strategy makes assumptions that if miscalculated could negatively impact the USAFs ability to provide the necessary aircraft fighter force for Homeland Defense and national security interests abroad. The USAF has identified the need for 2,200 tactical fighter aircraft in its inventory and that force takes many different shapes over the next 30 years.[192] The increased retirement rate of current F-16, F-15, and A-10 fighter aircraft combined with ending production of the F-22 places a significant burden on the F-35 program to provide the identified force needs. Policymakers are assuming this program will be able to meet the shortened production schedule and still perform at expected levels, as well as save money in the long run. It is difficult to say whether or not this will be the case but initial setbacks in the F-35 flight testing suggest the weapons program is subject to the same delays and cost overruns as previous programs like the F-22 setting the stage for a serious fighter shortfall.[193] On the other hand, if slowed production is countered by further service life extension plans for current fighter aircraft the cost implications of these plans would certainly be of significant concern just as they are today. In the meantime, competitors like Russia and China have the potential to significantly close the capability gap and pose a credible threat should the global security environment change during transition period.

While UCAVs have proven instrumental in current low threat conflicts, their reliability and survivability do not meet the requirements of most contested battlefield scenarios. The next generation in UCAV technology will undoubtedly be more capable

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[192] Elmendorf, *Alternatives for Modernizing U.S. Fighter Forces,* 7.

[193] Michael Sullivan, *Joint Strike Fighter: Strong Risk Management Essential as Program Enters Most Challenging Phase,* (Washington, D.C.: Government Accountability Office, 2009), 5.

but how long will it take to develop systems comparable to the prove effectiveness of current manned fighters and what will they cost? Current policy suggests costs have become the leading driving force in cost versus effectiveness comparisons. This approach has validity provided the sacrificed effectiveness does not produce a second rate military force. In the case of the F-22, the cost of procuring and maintaining a force size greater than 187, is seen as overkill based on expected future conflicts. In comparison, the current fight against violent extremist does not require such capabilities and the systems required are must less expensive making the shift that much more rational. In the end, when military force is employed to protect the U.S. and its interests abroad finishing second is not an option. The ability to predict the next war and build weapons systems just good enough to win is just about impossible. The U.S. has guaranteed its security by developing an overwhelming force should it be called upon to fight. If the current security environment continues the shift in mindset will be looked upon as genius. On the other hand, should tensions flare in regions such as Korea or Taiwan and China chooses to engage the U.S. will be in a higher risk position with the potential to seriously threaten its dominance in the future.

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